Multi-hazard Loss Estimation Methodology

Earthquake Model

HAZUS®*MH* MR3

User Manual

Developed by:

Department of Homeland Security
Federal Emergency Management Agency
Mitigation Division
Washington, D.C.

Under a contract with:
National Institute of Building Sciences
Washington, D.C.

FOREWORD

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HAZUS-MH to HAZUS-MH MR3

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MESSAGE TO USERS

The HAZUS Earthquake Model is designed to produce loss estimates for use by federal, state, regional and local governments in planning for earthquake risk mitigation, emergency preparedness, response and recovery. The methodology deals with nearly all aspects of the built environment, and a wide range of different types of losses. Extensive national databases are embedded within HAZUS, containing information such as demographic aspects of the population in a study region, square footage for different occupancies of buildings, and numbers and locations of bridges. Embedded parameters have been included as needed. Using this information, users can carry out general loss estimates for a region. The HAZUS methodology and software are flexible enough so that locally developed inventories and other data that more accurately reflect the local environment can be substituted, resulting in increased accuracy.

Uncertainties are inherent in any loss estimation methodology. They arise in part from incomplete scientific knowledge concerning earthquakes and their effects upon buildings and facilities. They also result from the approximations and simplifications that are necessary for comprehensive analyses. Incomplete or inaccurate inventories of the built environment, demographics and economic parameters add to the uncertainty. These factors can result in a range of uncertainty in loss estimates produced by the HAZUS Earthquake Model, possibly *at best* a factor of two or more.

The methodology has been tested against the judgment of experts and, to the extent possible, against records from several past earthquakes. However, limited and incomplete data about actual earthquake damage precludes complete calibration of the methodology. Nevertheless, when used with embedded inventories and parameters, the HAZUS Earthquake Model has provided a credible estimate of such aggregated losses as the total cost of damage and numbers of casualties. The Earthquake Model has done less well in estimating more detailed results - such as the number of buildings or bridges experiencing different degrees of damage. Such results depend heavily upon accurate inventories. The Earthquake Model assumes the same soil condition for all locations, and this has proved satisfactory for estimating regional losses. Of course, the geographic distribution of damage may be influenced markedly by local soil conditions. In the few instances where the Earthquake Model has been partially tested using actual inventories of structures plus correct soils maps, it has performed reasonably well.

Users should be aware of the following specific limitations:

- While the HAZUS Earthquake Model can be used to estimate losses for an individual building, the results must be considered as average for a group of similar buildings. It is frequently noted that nominally similar buildings have experienced vastly different damage and losses during an earthquake.

- When using embedded inventories, accuracy of losses associated with lifelines may be less than for losses from the general building stock. The embedded databases and assumptions used to characterize the lifeline systems in a study region are necessarily incomplete and oversimplified.

- Based on several initial studies, the losses from small magnitude earthquakes (less than M6.0) centered within an extensive urban region appear to be overestimated.

- Because of approximations in modeling of faults in California, there may be discrepancies in motions predicted within small areas immediately adjacent to faults.

- There is considerable uncertainty related to the characteristics of ground motion in the Eastern U.S. The embedded attenuation relations in the Earthquake Model, which are those commonly recommended for design, tend to be conservative. Hence use of these relations may lead to overestimation of losses in this region, both for scenario events and when using probabilistic ground motion.

HAZUS should still be regarded as a work in progress. Additional damage and loss data from actual earthquakes and further experience in using the software will contribute to improvements in future releases. To assist us in further improving HAZUS, users are invited to submit comments on methodological and software issues by letter, fax or e-mail to:

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LIMITATIONS OF THE HAZUS-MH MR3 SOFTWARE

Installation

- HAZUS-MH MR3 is certified to run on ArcGIS 9.2 SP2. Tests have shown that HAZUS-MH MR3 is unable to fully function on the ArcGIS 9.2 platform only. SP1 is required, but SP2 is preferable. ArcGIS 9.2 SP2 is available from the ESRI website.

- HAZUS-MH MR3 is certified to run on MS Windows 2000 SP4 and Windows XP SP2. A user is allowed to install HAZUS-MH MR3 on MS Windows 2000 and XP for Service Packs higher than SP4 and SP2 respectively, but HAZUS-MH MR3 is not certified to work flawlessly with those service packs.

- HAZUS-MH MR3 must be uninstalled only with the windows Add/Remove Programs utility. For details on uninstalling, please consult the User Manuals.

- Users who plan to operate HAZUS-MH MR3 in a network environment will be able to perform HAZUS operations, such as importing, but not study region creation.

Study Region Size

- The database management system of HAZUS-MH MR3 is SQL 2005 Express. This system has a size limit of 4 GB per database; which limits the size of the region that can be created to about 3,000 census tracts, equivalent to an area with a population of about 9 million. For a multi-hazard study region that includes data for all three hazards, the 4 GB limit will permit an even smaller study region. To work around this, the full version of Microsoft SQL Server 2005 Workgroup, Standard, Enterprise Editions must be used (see Appendix N in the user manuals).

- Multihazard loss analysis capability is limited to the 23 states that experience hurricane, flood and earthquake hazards and requires that the user first run annualized losses for each of the three hazards.

- To maximize the size of the study region that may be analyzed, set the virtual memory size from a minimum of 2048 MB to a maximum of 4096 MB. For the earthquake model, the virtual memory size may be increased from a minimum of 1024 MB to a maximum of 2048 MB for optimal operation. Here are the steps for setting the virtual memory size (in Windows XP. See page 2-32 for Windows 2000):

  1- Click on Start | Settings | Control Panel | System

  2- Click on the Advanced Tab

3- Click on the Settings button under the Performance group
4- Click on the Advanced tab5- Click the Change button under Virtual Memory
6- Replace the initial and maximum values
7- Click Set then OK three times to exit to the main screen.

- To speed up the study region aggregation process, state databases can be copied to the local hard-disk. If necessary, the Registry can be updated so that HAZUS-MH looks to the location where you copied the data on the local hard disk rather than to the default DVD location.

  The HAZUS-MH MR3 installation allows the user to specify the folder where the state data will be copied through the "Choose Data Path" dialog in the installation wizard. If, at the time of installation, the user specifies the folder where the data will be copied after installation, they only need to perform Step 1 as described below. If at the time of installation the User does not specify the folder where the state data will be copied by the user after installation, or if they want to change the folder specified during installation, then Steps 2 through 4 for updating the Registry should be completed.

  NOTE: The "Choose Data Path" dialog in the installation process only specifies the folder where the state data will be copied by the user from the DVD after installation has completed. This dialog doesn't copy the data from the DVD to the specified folder; that has to be done manually by the user after installation.

  1- Copy one or more of the state data folders (e.g., NC1), both the DVD identification files (e.g., D1.txt ^ 4.txt) and "syBoundary.mdb" from the Data DVD to a folder on your hard drive (e.g., D:\HAZUSData\). As an example, the following graphic illustrates how the data for the state of South Carolina would be organized under the HAZUS Data folder.

  2- Next, point the program to the data folder on your local hard drive. To do this, click the "Start" button and select "Run" to open the Run window, type "regedit" in the Run window edit box and click the "OK" button to open the Registry Editor. Navigate through the folders listed in the Registry Editor to the following location:

  HKEY_LOCAL MACHINE | SOFTWARE | FEMA | HAZUS-MH | General

  3- Now look at the right side of the window and find the entry called "DataPath1".
  Double click on "DataPath1" to open the Edit String window and enter the full name of the folder on the hard drive that contains the data copied from the DVDs in the edit box. Click the OK button to update the DataPath1 value.

  IMPORTANT: Make sure the path ends with a "\" and do not change any of the other registry settings.

4- Close the Registry Editor by choosing Exit from the File menu of the Registry Editor.

Capabilities

- Transferring data, including importing study regions, from HAZUS99, HAZUS99-SR1, HAZUS99-SR2, HAZUS-MH and HAZUS-MH MR1 to HAZUS-MH MR3 will require the assistance of technical support.

- Inventory data and subsequently the Level 1 analysis functionality are unavailable for the US held territories, but are available for Puerto Rico.

- Components of independently developed data sets in the default inventory data might not line up on maps, for example, the placement of bridges and roads, and facilities. This situation can be addressed by updating the default inventory data with user supplied data.

- Rapid loss estimates for large study regions of 1000-2000 census tracts might require 0.5 to 1.5 hours analysis time.

InCAST

- Since InCAST development predated the development of the Earthquake Model in HAZUS-MH, data types used for different types of hazard specific data in InCAST are not compatible with those used in HAZUS-MH MR3. Additionally, InCAST does not capture all hazard specific attributes used in HAZUS-MH MR3.

  InCAST can be used to capture earthquake hazard data which can be imported into HAZUS-MH MR3 from hzIncast table. However, the following fields should not be imported: BldgType, Kitchen, Dinning and Sleeping. The full capability of InCAST can be used to capture data for import into the inventory table of the AEBM module.

Technical Support

- Technical support is available via telephone, e-mail, or FAX. The numbers and addresses are listed on the HAZUS software package and under the Help menu in the software. Information on HAZUS updates, software patches, and FAQs are available at www.fema.gov/hazus/.

WHAT'S NEW IN HAZUS-MH - EARTHQUAKE MODEL

Data

- New 2002 aggregated data for square footage, building count, building exposure, content exposure and demographics.
- New site specific inventory data (2000 or later)
- New 2002 USGS probabilistic ground shaking maps and new USGS attenuation functions
- Multi-famility dwellings (RES3) are split into five categories Duplex (RES3A), Triplex / Quads (RES3B), Multi-dwellings - 5 to 9 units (RES3C), Multi-dwellings - 10 to 19 units (RES3D), Multi-dwellings - 20 to 49 units (RES3E) and Multi-dwellings - 50+ units (RES3F).
- Expansion of attributes in the Demographics data. The following categories were added: Gender information, more income brackets, number of students and building count by age.
- Precompiled default replacement values for all site specific data

Methodology

- Direct usage of square footage, building exposure and content exposure in building damage and economic loss computations
- Streamlined the restoration functions for pipelines. Now all pipelines are restored in the same ways as potable water pipelines.
- Streamlined damage for bridges
- Lifeline buildings will now use pushover analysis for damage computations
- Facility added in the Sceanario Wizard to set the whole study region one soil type, liquefaction susceptibility category, and landslide susceptibility category and water depth.
- Show current scenario dialog modified to view current hazard settings for soil, liquefaction landslide and water depth.
- Occupancy mapping scheme can be viewed by Specific Occupancy to General Building type relation and withing every such relation as a General Building Type to Specific Building Type distribution.
- Streamlined economic parameters into inventory replacement values and loss ratios by damage states.

Other Features:

- New three tier application architecture that can be esily ported for internet based implementation.
- New Hazard Query Wizard to handle complex relational queries with the underlying MSDE database.
- Feature added to enable third party modules. Currently ALOHA/MARPLOT and FLDWV/FLDVIEW have been enabled. Refer to Appendix L and Appendix M of Users Manual for details.

WHAT'S NEW IN HAZUS-MH MR1 EARTHQUAKE MODEL

Data
- Updated USGS probabilistic hazard data.
- Updated valuations for the general building stock.
- Data for Puerto Rico.

Methodology
- Capability to port USGS Shake maps into the HAZUS-MH MR1 geodatabase format.
- Capability to add new custom building types.

Other Features
- Operation on the new ArcGIS 9.0 SP1 platform.
- Capability to run HAZUS-MH MR1 without administrative rights.
- Optimized software for rapid loss assessment.

WHAT'S NEW IN HAZUS-MH MR2 EARTHQUAKE MODEL

Data

- 2005 valuation data for all occupancy classes.
- Means location factors for residential and non-residential occupancies on a county basis.
- Updated and validated valuation data for single-family residential housing and manufactured housing based on comparisons with other national databases.
- Zeros substituted for any negative values calculated for the daytime, nighttime, working commercial, working industrial and commuting populations.
- Construction age and values by decade for every census block with floor area (square footage).

Methodology

- Optimized Building Damage Module that uses seven combinations of design levels and building quality levels (reduced from nine) as follows.

  1) High – Code
  2) Moderate – Code
  3) Low – Code
  4) Pre – Code
  5) Special High – Code
  6) Special Moderate – Code
  7) Special Low – Code

- Technical Manual Chapter 4 guidance for selecting attenuation functions.
- Corrected Wyoming and Montana default mapping schemes.

Other Features

- Updated BIT that is coordinated with the seven combinations of design levels and building quality levels in the Building Damage Module.
- Keyboard operation of all user interface operations with some exceptions.

- Operation on the ArcView 9.1 SP1 platform.
- Certified on Windows XP SP2.
- Operation on the MDAC 2.8 data access engine from Microsoft.

What's New in HAZUS-MH MR3

Data

- Commercial data updated to Dun & Bradstreet 2006.
- Building valuations updated to R.S. Means 2006.
- Building counts based on census housing unit counts for RES1 (single-family dwellings) and RES2 (manufactured housing) instead of calculated building counts.

Methodology

- Population distribution parameters adjustable in the casualty module through SQL Express.
- Partial ignitions eliminated in the fire-following module

Other Features

- Operation on the ArcView 9.2 SP2 platform.
- Operation on Microsoft SQL 2005 Express.
- Operation on the MDAC 2.8 SP1 data access engine form Microsoft.
- Operation FarPoint Spread 7 – Spreadsheet
- Operation on Crystal Reports 11.
- Enancements to the existing aggregation routines to reflect improved procedures for processing study region information.

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Chapter 1. Introduction to the Earthquake Loss Estimation Methodology

The earthquake loss estimation provides local, state and regional officials with a state-of-the-art decision support tool for estimating potential losses from scenario earthquakes. This forecasting capability will enable users to anticipate the consequences of future earthquakes and to develop plans and strategies for reducing risk. The GIS-based software can be applied to study small or large geographic areas with a wide range of population. **HAZUS** will accommodate budget constraints, and can be implemented by users with varying technical and subject expertise. The modular approach of the methodology (with different modules addressing various user needs) provides additional flexibility in a variety of applications.

The various users of a loss estimation study will have different needs. A local or state government official may be interested in the costs and benefits of specific mitigation strategies, and thus may want to know the expected losses if mitigation strategies have been applied. Health officials will want information about the demands on medical care facilities and will be interested in the number and severity of casualties for different scenario earthquakes. Fire fighters may be interested in areas where large fires can be expected or where hazardous materials might be released. Emergency response teams may use the results of a loss study in planning and performing emergency response exercises. In particular, they might be interested in the operating capacity of emergency facilities such as fire stations, emergency operations centers, and police stations. Emergency planners may want to know how much temporary shelter will be needed and for how long. Utility company representatives, as well as planners want to know about the locations and lengths of potential utility outages. Federal and state government officials may require an estimate of economic losses (both short term and long term) in order to direct resources toward affected communities. In addition, government agencies may use loss studies to obtain quick estimates of impacts in the hours immediately following an earthquake so as to best direct resources to the disaster area. Insurance companies may be interested in monetary losses so they can assess their exposure. This list of uses of earthquake loss estimation studies is not comprehensive. As users become familiar with the loss estimation methodology, they will determine which **HAZUS** modules are most appropriate for their needs, and how to interpret the study results.

Some of the first earthquake loss estimation studies were performed in the early 1970’s following the 1971 San Fernando earthquake. These earlier studies were funded by Federal agencies and were intended to provide a basis for disaster relief and recovery. These studies put a heavy emphasis on loss of life, injuries and the ability to provide emergency health care. More recent studies have focused on disruption to roads, telecommunications and other lifeline systems. An understanding of disruptions to these systems is essential in planning for post earthquake emergency response. More recently, municipalities have invested in earthquake loss estimation methodologies based on geographic information systems (GIS). These municipalities have found that as inventories are collected, they may be useful for purposes beyond the scope of earthquake loss estimation. For example, data collected for an earthquake loss estimation model in San Bernardino County, California (FEMA, 1985) are now being used for city planning purposes.

Two useful resources on loss estimation studies are “Estimating Losses from Future Earthquakes” (FEMA, 1989) and “Assessment of the State-of-the-Art of Earthquake Loss Estimation Methodologies” (FEMA, 1994). Other useful applications of earthquake loss estimation methodologies are contained in “Comprehensive Earthquake Preparedness Planning Guidelines” (FEMA, 1985) and “A Cost Benefit Model for the Seismic Rehabilitation of Buildings” (FEMA, 1992).

1.1 Overview of the Methodology

This brief overview of the earthquake loss estimation methodology is intended for local, regional, or state officials contemplating an earthquake loss study. The methodology has been developed for the Federal Emergency Management Agency (FEMA) by the National Institute of Building Sciences (NIBS) to provide a tool for developing earthquake loss estimates for use in:

- Anticipating the possible nature and scope of the emergency response needed to cope with an earthquake-related disaster,
- Developing plans for recovery and reconstruction following a disaster, and
- Mitigating the possible consequences of earthquakes.

If developed for areas of seismic risk across the nation, estimates also will help guide the allocation of federal resources to stimulate risk mitigation efforts and to plan for federal earthquake response.

Use of the methodology will generate an estimate of the consequences to a city or region of a "scenario earthquake", i.e., an earthquake with a specified magnitude and location. The resulting "loss estimate" generally will describe the scale and extent of damage and disruption that may result from a potential earthquake. The following information can be obtained:

- *Quantitative estimates of losses* in terms of direct costs for repair and replacement of damaged buildings and lifeline system components; direct costs associated with loss of function (e.g., loss of business revenue, relocation costs); casualties; people displaced from residences; quantity of debris; and regional economic impacts.
- *Functionality losses* in terms of loss-of-function and restoration times for critical facilities such as hospitals, and components of transportation and utility lifeline systems and simplified analyses of loss-of-system-function for electrical distribution and potable water systems.
- *Extent of induced hazards* in terms of fire ignitions and fire spread, exposed population and building value due to potential flooding and locations of hazardous materials.

To generate this information, the methodology includes:

- Classification systems used in assembling inventory and compiling information on the building stock, the components of highway and utility lifelines, and demographic and economic data.
- Standard calculations for estimating type and extent of damage, and for summarizing losses.
- National and regional databases containing information for use as default (built-in) data, in the absence of user-supplied data., and useable in calculation of losses.

These systems, methods, and data have been combined in the development of user-friendly GIS software for this loss estimation application. GIS technology facilitates the manipulation of data on building stock, population, and the regional economy. The current version of the software (**HAZUS-MH MR3**) can only be run on one GIS platform, ArcView 9.2 SP12.

The software makes use of GIS technologies for displaying and manipulating inventory, and permitting losses and consequences to be portrayed on both spreadsheets and maps. Collecting and entering the necessary information for analysis are the major tasks involved in generating a loss estimate. The methodology permits estimates to be made at several levels of sophistication, based on the level of inventory entered for the analysis (i.e., default data versus locally enhanced data). The better and more complete the inventory information, the more meaningful the results.

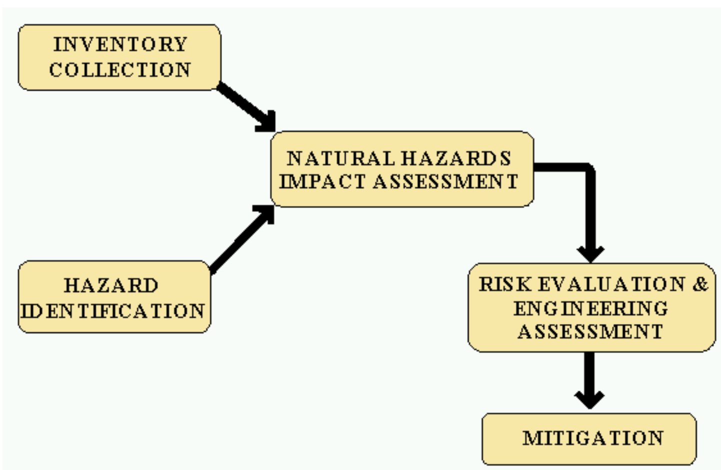


Figure 1.1 Steps in assessing and mitigating losses due to natural hazards

Figure 1.1 Steps in assessing and mitigating losses due to natural hazards shows the steps that are typically performed in assessing and mitigating the impacts of a natural hazard such as an earthquake. The methodology incorporates inventory collection, hazard identification, and the natural hazards impact assessment. In a simplified form, the steps include:

- Select the area to be studied. The region of interest is created based on Census Tract, Census Block, county, or state. The area generally includes a city, county, or group of municipalities. It is generally desirable to select an area that is under the jurisdiction of an existing regional planning group.
- Specify the magnitude and location of the scenario earthquake. In developing the scenario earthquake, consideration should be given to the potential fault locations.
- Provide additional information describing local soil and geological conditions, if available. Soil characteristics include site classification according to the National Earthquake Hazard Reduction Program (NEHRP) and susceptibility to landslides.
- Using formulas embedded in HAZUS, probability distributions are computed for damage to different classes of buildings, facilities, and lifeline system components. Loss-of-function is also estimated.
- The damage and functionality information is used to compute estimates of direct economic loss, casualties and shelter needs. In addition, the indirect economic impacts on the regional economy are estimated for the years following the earthquake.
- An estimate of the number of ignitions and the extent of fire spread is computed. The amount and type of debris are estimated. If an inundation map is provided, exposure to flooding can also be estimated.

The user plays a major role in selecting the scope and nature of the output of a loss estimation study. A variety of maps can be generated for visualizing the extent of the losses. Numerical results may be examined at the level of the census tract, or may be aggregated by county or region.

1.2 Earthquake Hazards Considered in the Methodology

The earthquake-related hazards considered by the methodology in evaluating casualties, damage, and resultant losses are collectively referred to as *potential earth science hazards* (PESH). Most damage and loss caused by an earthquake is directly or indirectly the result of *ground shaking*. Thus, it evaluates the geographic distribution of ground shaking resulting from the specified scenario earthquake and expresses ground shaking using several quantitative parameters, ex. peak ground acceleration and spectral acceleration.

Three other features of earthquakes that can cause permanent ground displacements and have an adverse effect upon structures, roadways, pipelines, and other lifeline structures also are considered:

- *Fault rupture*: Ground shaking is caused by fault rupture, usually at some depth below the ground surface. However, fault rupture can reach the surface of the earth as a narrow zone of ground offsets and tear apart structures, pipelines, etc. within this zone.
- *Liquefaction*: This sudden loss of strength and stiffness in soils can occur when loose, water-saturated soils are shaken strongly and can cause settlement and horizontal movement of the ground.
- *Landsliding*: This refers to large downhill movements of soil or rock that are shaken free from hillsides or mountainsides which can destroy anything in their path.

Soil type can have a significant effect on the intensity of ground motion at a particular site. Soil, as defined in this methodology is classified in terms of geology. The software contains several options for determining the effect of soil type on ground motions for a given magnitude and location. The user may select the default classifications, or choose an alternative.

Tsunamis (waves moving across oceans) and seiches (oscillatory waves generated in lakes or reservoirs) are also earthquake-caused phenomena that can result in inundation or waterfront damage. In the methodology, potential sites of these hazards may be identified, but they are evaluated only if special supplemental data are provided.

The definition of the scenario earthquake is not just a matter of earth science. Hazard management and political factors must be considered as well. Planning for mitigation and disaster response generally is based on large, damaging events, but the probability that such events will occur also should be considered. In a region of high seismicity, the *maximum credible earthquake* is generally a suitable choice. In areas of lower seismicity, it is prudent to assume a very large earthquake event is possible, although unlikely. In such regions, it is often most appropriate to choose an earthquake with a specified mean recurrence interval, such as the "500-year earthquake." Consideration should be given to calculating losses using several scenario earthquakes. Each scenario would be defined by different magnitudes, locations, and probabilities of occurrence, since these factors are a major source of uncertainty.

Data concerning past earthquakes are provided within HAZUS. Chapter 9 provides guidance concerning the selection of scenario earthquakes. It is always desirable to consult local earth science experts during the process of choosing scenario events.

1.3 Types of Buildings and Facilities Considered

The buildings, facilities, and lifeline systems considered by the methodology are as follows:

- *General building stock*: The majority of commercial, industrial and residential buildings in your region are not considered individually when calculating losses. Buildings within each census tract are aggregated and categorized. Building information derived from Dunn & Bradstreet data are used to form groups of 36 model building types and 33 occupancy classes. Degree of damage is computed for each group combination of model building type and occupancy class.

Examples of model building types are light wood frame, mobile home, steel braced frame, concrete frame with unreinforced masonry infill walls, and unreinforced masonry. Each model building type is further subdivided according to typical number of stories and apparent earthquake resistance (based primarily upon the earthquake zone where they are constructed). Examples of occupancy types are single family dwelling, retail trade, heavy industry, and churches. All structures are categorized in this manner and referred to as General Building Stock or GBS in short.

- *Essential facilities*: Essential facilities, including medical care facilities, emergency response facilities and schools, are those vital to emergency response and recovery following a disaster. School buildings are included in this category because of the key role they often play in housing people displaced from damaged homes. Generally there are very few of each type of essential facility in a census tract, making it easier to obtain site-specific information for each facility. Thus, damage and loss-of-function are evaluated on a building-by-building basis for this class of structures, even though the uncertainty in each such estimate is large.
- *Transportation lifeline systems*: Transportation lifelines, including highways, railways, light rail, bus systems, ports, ferry systems and airports, are broken into components such as bridges, stretches of roadway or track, terminals, and port warehouses. Probabilities of damage and losses are computed for each component of each lifeline; however, total *system* performance cannot be evaluated (for example, how well various sections, nodes and connections of the total system perform to enable to move from point A to point B after an earthquake).
- *Utility lifeline systems*: Utility lifelines, including potable water, electric power, waste water, communications, and liquid fuels (oil and gas), are treated in a manner similar to transportation lifelines. Examples of components are electrical substations, water treatment plants, tank farms and pumping stations.
- *High potential loss facilities:* In any region or community there will be certain types of structures or facilities for which damage and losses will not be (reliably) evaluated without facility-specific supplemental studies. Such facilities include dams, nuclear power plants, liquefied natural gas facilities, military installations, and large one-of-a-kind residential or commercial structures.

  It would be potentially misleading to estimate damage and losses of these structures without a detailed engineering analysis performed with the agreement of the facility owner. The general approach is to call attention to these facilities, include their locations in the inventory, and indicate a potential for loss in the final report. Although the loss cannot be quantified without further investigation, the location of the structures with respect to ground failure or intense ground motions may provide a starting point for more in-depth studies. To include these structures in the loss estimation study outputs, results from supplemental studies, such as damage-motion curves, can be entered.

1.4 Levels of Analysis

To provide flexibility, the losses are estimated at three levels. The first level only uses default inventory and parameter data. The second level of estimation is achieved by improving inventories and/or parameters with user-supplied data. The third level of loss estimation incorporates data from third-party studies. The appropriate level of analysis must be determined to meet the needs of the user.

1.4.1 Analysis Based on Default Information

The basic level of analysis uses only the default databases built into the methodology for information on building square footage and value, population characteristics, costs of building repair, and certain basic economic data. One average soil condition is assumed for the entire study region. The effects of possible liquefaction and landsliding are ignored. Direct economic and social losses associated with the general building stock and essential facilities are computed. Default data for transportation and utility lifelines are included, thus these lifelines are considered in the basic level of analysis. Uncertainty, however, is large. Fire ignitions and fire spread are considered using a simplified model. Indirect economic impacts for the region are calculated but are based on a synthetic economy that may or may not accurately reflect the characteristics of the region. Table 1.1 summarizes the output that can be obtained from an analysis. Outputs that cannot be obtained using only default data are marked with a footnote.

Table 1.1. Earthquake Loss Estimation Methodology Output

Maps of seismic hazards • Intensities of ground shaking for each census tract • Contour maps of intensities of ground shaking • Permanent ground displacements for each census tract* • Contour map of permanent ground displacements* • Liquefaction probability* • Landsliding probability* **Characterization of damage to general building stock** • Structural and nonstructural damage probabilities by census tract, building type and occupancy class. **Transportation and utility lifelines** • For components of the 13 lifeline systems: damage probabilities, cost of repair or replacement and expected functionality for various times following earthquake • For all pipeline systems: the estimated number of leaks and breaks • For potable water and electric power systems: estimate of service outages **Essential facilities** • Damage probabilities • Probability of functionality • Loss of beds in hospitals **High potential loss facilities (HPLF)** • Locations of dams • Locations of nuclear plants • Damage probabilities and cost of repair for of military facilities* • Locations of other identified HPLs	**Fire following earthquake** • Number of ignitions by census tract • Percentage of burned area by census tract **Inundated areas** • Exposed population and exposed dollar value of general building stock* **Hazardous material sites** • Location of facilities which contain hazardous materials **Debris** • Total debris generated by weight and type of material **Social losses** • Number of displaced households • Number of people requiring temporary shelter • Casualties in four categories of severity based on three different times of day **Dollar losses associated with general building stock** • Structural and nonstructural cost of repair or replacement • Loss of contents • Business inventory loss • Relocation costs • Business income loss • Employee wage loss • Loss of rental income **Indirect economic impact** • Long-term economic effects on the region based on a synthetic economy • Long-term economic effects on the region based on an IMPLAN model*

* Outputs cannot be obtained using only default data.

Other than defining the study region, selecting the scenario earthquake(s) and making decisions concerning the extent and format of the output, an analysis based on default data requires minimal effort from the user. As indicated, estimated losses are incomplete and the estimates involve large uncertainties when inventories are limited to the default data. This level of analysis is suitable primarily for preliminary evaluations and crude comparisons among different study regions with a Census Block as the smallest regional unit.

1.4.2 Analysis with User-Supplied Inventory

Results from an analysis using only default inventory can be improved greatly with at least a minimum amount of locally developed input. This is generally the intended level of implementation (Level II). Table 1.1 summarizes the output that can be obtained from this level of analysis. Improved results are highly dependent on the quality and quantity of improved inventories. Significance of the improved results also relies on the user's analysis priorities. The following inventory improvements impact the accuracy of analysis results.

- Development of maps of soil conditions affecting ground shaking, liquefaction and landsliding potential. These maps would be used for evaluation of the effects of these local conditions upon damage and losses.
- Use of locally available data or estimates concerning the square footage of buildings in different occupancy classes.
- Use of local expertise to modify, primarily by judgment, the databases concerning percentages of model building types associated with different occupancy classes.
- Preparation of a detailed inventory for all essential facilities.
- Collection of detailed inventory and cost data to improve evaluation of losses and lack of function in various transportation and utility lifelines.
- Use of locally available data concerning construction costs or other economic parameters.
- Collections of data, such as number of fire trucks, for evaluation of the probable extent of areas affected by fires.
- Development of inundation maps.
- Gathering of information concerning high potential loss facilities and facilities housing hazardous materials.
- Synthesis of data for modeling the economy of the study region used in calculation of indirect economic impacts.

User-supplied inventory can require months of dedicated work to prepare. The extent of preparation and data compilation work involved depends on the condition and completeness of existing information, required data conversions, and the contributions of expertise. The greatest impact from enhanced inputs are produced by editing both the basic inventory and updating the model parameters. These input improvements are best accomplished by a cooperative team effort. Strategic planning is required to estimate and execute the level of effort required to produce the useful analysis outputs.

The most detailed type of analysis incorporates the results from completed loss studies. For example, it is possible to include the output of loss estimates performed using locally developed traffic models that have identifed the bridges most susceptible to damage. Similar analyses can provide information on water distribution or other pipeline systems. Review and updates to the vulnerability ratings for each model building type will also produce more accurate analysis results.

It is advisable to run a baseline analysis for comparison with results after introduction of user-supplied data. Sensitivity of the loss estimation methodology under local conditions is measured best by review of outputs after inclusion of each enhanced inventory. Good record-keeping and inventory documentation are essential.

1.5 Assumed Level of Expertise of Users

Users can be broken into two groups: those who perform the study, and those who use the study results. For some studies these two groups will consist of the same people, but generally this will not be the case. However, the more interaction that occurs between these two groups, the better the study will be. End users of the loss estimation study need to be involved from the beginning to make results more usable.

Those who are performing the study must, at minimum, have a basic understanding of earthquakes, their causes and their consequences. In many cases, the results will be presented to audiences (i.e. city councils and other governing bodies) that have little technical knowledge of the earthquake loss problem.

It is assumed that a loss study will be performed by a representative team consisting of geologists, geotechnical engineers, structural engineers, architects, economists, sociologists, hydrologists, emergency planners, public works personnel, and loss estimate users. These individuals are needed to develop earthquake scenarios, identify problematic soils, develop and classify building inventories, provide and interpret economic data, provide information about the local population, and to provide input on what loss estimates are needed to fulfill the study goals. At least one GIS specialist must participate on the team, and others with some level of familiarity or expertise in data management and GIS are beneficial.

If a local or state agency is performing the study, some of the expertise can be found in-house. Experts are generally found in several departments: building permits, public works, planning, public health, engineering, information technologies, finance, historical preservation, natural resources, and land records. Although internal expertise may be most readily available, participation of individuals from academic institutions, citizen organizations, and private industry cannot be underestimated.

1.5.1 When to Seek Help

The results of a loss estimation study should be interpreted with caution. Application of default input values have a great deal of uncertainty associated with them. If the loss estimation team does not include individuals with expertise in the areas described above, then it is likely that one or more outside consultants may be required to assist with interpreting the results. It is also advisable to retain objective reviewers with subject expertise to evaluate and comment on map and tabular data outputs.

A seismologist will be needed to provide, or review each scenario earthquake, and to describe it in terms of moment magnitude (M), spectral velocity and spectral acceleration. Attention should be given to any differences in the methodology used to define documented scenarios. A scenario event that is defined without an in-depth understanding of earthquake sources, recurrence and the geology of the region, may not be appropriate for the loss study.

If the user intends to modify the default inventory data or parameters, assistance will be required from an individual with expertise in the subject. For example, if the user wishes to change default percentages of model building types for the region, a structural engineer with knowledge of regional design and construction practices will be helpful. Similarly, if damage-motion relationships (fragility curves) need editing, input from a structural engineer will be required. Modifications to defaults in the direct and indirect economic modules will require input from an economist.

Technical help for the users of HAZUS has been established by NIBS. Users should contact FEMA or NIBS at the email, phone, fax, or addresses provided in this manual for information on technical support. Agency and organizational websites are also listed in this report to access Frequently Asked Questions (FAQs), software updates, training opportunities, and User Group activities.

1.6 Displaying Analysis Results

There is a great deal of flexibility in displaying output. Tables of social and economic losses can be displayed on the screen, printed, or pasted into electronic documents. Most outputs can also be mapped. Colors, legends and titles can be easily altered. Results can be compiled to create electronic presentations, or as inserts to a community project report.

Examples of graphical and numerical outputs that can be produced by the program are found in Figures 1.2 and 1.3.

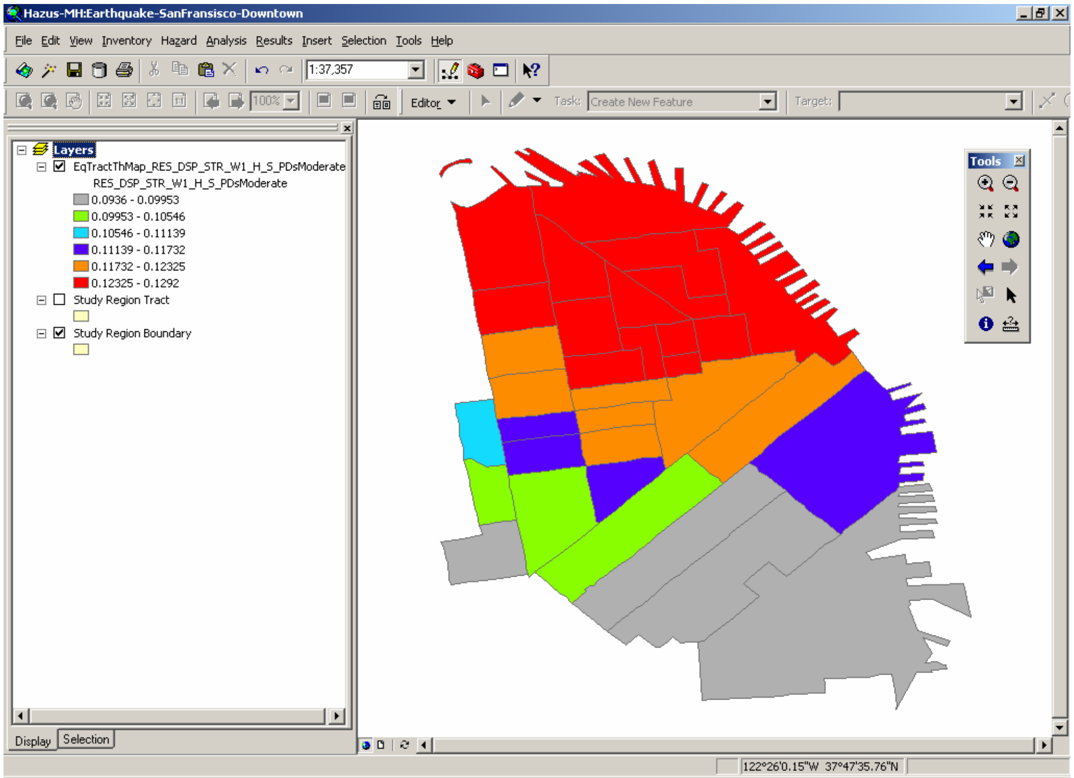
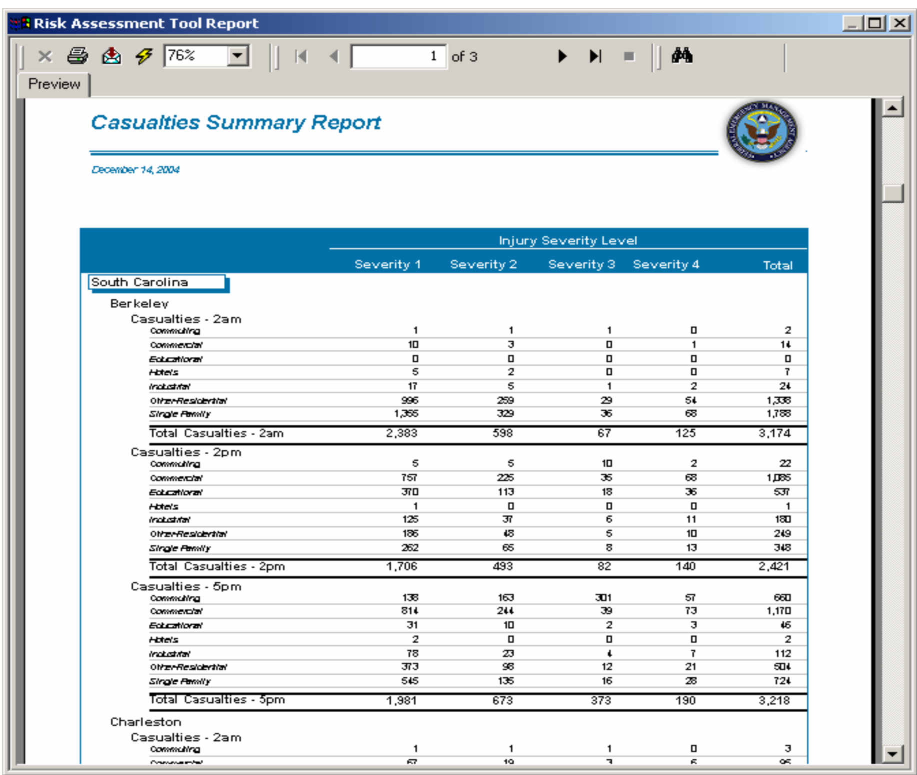


Figure 1.2 Sample output: damage to wooden residential structures.



Casualties Summary Report

December 14, 2004

	Injury Severity Level				
	Severity 1	Severity 2	Severity 3	Severity 4	Total
South Carolina					
Berkeley					
Casualties - 2am					
Commuting	1	1	1	0	2
Commercial	10	3	0	1	14
Educational	0	0	0	0	0
Hotels	5	2	0	0	7
Industrial	17	5	1	2	24
Other-Residential	996	259	29	54	1,338
Single Family	1,355	329	36	68	1,788
Total Casualties - 2am	2,383	598	67	125	3,174
Casualties - 2pm					
Commuting	5	5	10	2	22
Commercial	757	225	35	68	1,085
Educational	370	113	18	36	537
Hotels	1	0	0	0	1
Industrial	125	37	6	11	180
Other-Residential	186	48	5	10	249
Single Family	262	65	8	13	348
Total Casualties - 2pm	1,706	493	82	140	2,421
Casualties - 5pm					
Commuting	138	163	301	57	660
Commercial	814	244	39	73	1,170
Educational	31	10	2	3	46
Hotels	2	0	0	0	2
Industrial	78	23	4	7	112
Other-Residential	373	98	12	21	504
Single Family	545	135	16	28	724
Total Casualties - 5pm	1,981	673	373	190	3,218
Charleston					
Casualties - 2am					
Commuting	1	1	1	0	3

Figure 1.3 Sample output: Casualties' summary report.

1.7 Uncertainties in Loss Estimates

Although the software offers users the opportunity to prepare comprehensive loss estimates, it should be recognized that, even with state-of-the-art techniques, uncertainties are inherent in any such estimation methodology.

History has taught that the next major earthquake to affect a U.S. city or region will likely be quite different from the "scenario earthquake" anticipated as part of an earthquake loss estimation study. The magnitude and location of the earthquake and the associated faulting, ground motions and landsliding will not be precisely what was anticipated. Hence, the results of an earthquake loss study should not be looked upon as a *prediction*. Instead, it is only an indication of what the future may hold. This is particularly true in areas where seismicity is poorly understood.

Any region or city studied will have an enormous variety of buildings and facilities of different sizes, shapes, and structural systems constructed over years under diverse seismic design codes. Similarly, many types of components with differing seismic resistance will make up transportation and utility lifeline systems. Due to this complexity, relatively little is certain concerning the structural resistance of most buildings and other facilities. Further, there simply are not sufficient data from past earthquakes or laboratory experiments to permit precise predictions of damage based on known ground motions even for specific buildings and other structures. To deal with this complexity and lack of data, buildings and components of lifelines are lumped into categories, based upon key characteristics. Relationships between key features of ground shaking and average degree of damage with associated losses for each building category are based on current data and available theories. While state-of-the-art in terms of loss estimation, these relationships do contain a certain level of uncertainty.

Ranges of potential losses are best evaluated by conducting multiple analyses and varying certain input parameters to which the losses are most sensitive. Guidance for planning *sensitivity studies* is found in Section 9.7.

1.8 Applying Methodology Products

The products of the FEMA methodology for estimating earthquake losses have several pre-earthquake and/or post-earthquake applications in addition to estimating the scale and extent of damage and disruption.

Examples of pre-earthquake applications of the outputs are as follows:

- *Development of earthquake hazard mitigation strategies* that outline polices and programs for reducing earthquake losses and disruptions indicated in the initial loss estimation study. Strategies can involve rehabilitation of hazardous existing buildings (e.g., unreinforced masonry structures), building code enforcement, development of appropriate zoning ordinances for land use planning in areas of liquefiable soils, and the adoption of advanced seismic building codes.

- *Development of preparedness (contingency) planning measures* that identify alternate transportation routes and planning earthquake preparedness and survival education seminars.
- *Anticipation of the nature and scope of response and recovery efforts* including: identifying alternative housing and the location, availability and scope of required medical services; and establishing a priority ranking for restoration of water and power resources.

Post-earthquake applications of the outputs would include:

- *Projection of immediate economic impact assessments for state and federal resource allocation and support* including supporting the declaration of a state and/or federal disaster by calculating direct and indirect economic impact on public and private resources, local governments, and the functionality of the area.
- *Activation of immediate emergency recovery efforts* including search and rescue operations, rapid identification and treatment of casualties, provision of emergency housing shelters, control of fire following earthquake, and rapid repair and availability of essential utility systems.
- *Application of long-term reconstruction plans* including the identification of long-term reconstruction goals, implementation of appropriate wide-range economic development plans for the impacted area, allocation of permanent housing needs, and the application of land use planning principles and practices.

Once inventory has been collected, making modifications and running new analyses are simple tasks. The ease with which reports and maps can be generated makes the software a useful tool for a variety of applications.

1.9 Organization of the Manual

The *User's Manual* provides the background and instructions for developing an inventory to complete an earthquake loss estimation study using HAZUS. It also provides information on how to install and run the software, and how to interpret and report model output. The contents and organization of the User's Manual are outlined below.

The Technical Manual accompanies this publication. It documents the default data and explains the methods of calculating losses. Together, the two manuals provide a comprehensive overview of the nationally applicable loss estimation methodology.

Chapter 1 provides the user with a general understanding of the purpose, uses and components of a regional earthquake loss estimation study.

Chapter 2 gives instructions for installing and starting HAZUS-MH MR3.

Chapter 3 runs through an analysis using only default data.

Chapter 4 provides an overview of the types of data required to run the loss study, as well as a description of the default databases.

Chapter 5 contains detailed information about what data are needed to complete a loss study, sources of inventory, how to collect inventory, and related expenses to anticipate. This chapter also describes how to convert data to the correct format for the methodology, and how to enter data into HAZUS.

Chapter 6 includes instructions for entering data, editing records and geocoding addresses.

Chapter 7 provides the user with a discussion of how to display, modify and print databases.

Chapter 8 discusses The Building Data Import Tool (BIT). This utility is designed to help the user analyze and query existing databases to develop general building stock inventory information.

Chapter 9 provides a detailed step-by-step description of how to run an analysis using HAZUS, including analysis with user-supplied data.

Chapter 10 discusses how to view results and provides suggestions about putting together a report.

Chapter 11 contains a general discussion of vulnerability to natural hazards and key factors that should be considered in estimating losses as well as brief discussions of supplemental data that are available with HAZUS.

The *User's Manual* is written in language that should be easily understood by a user of the methodology. Highly technical terms are avoided where possible, but a glossary of terms is provided in Appendix H to supplement any definitions that are needed. A compilation of relevant references is found in References Section.

The appendices contain detailed information about the structure of the methodology.

Appendix A is the installation verification document.

Appendix B lists all of the classification systems that are used.

Appendices C and D provide descriptions of the model building types and lifeline components that are used in the methodology.

Appendix E describes the content and origin of the default databases.

Appendix F is a database dictionary containing details about the format of all of the databases used by HAZUS.

Appendix G includes a sample questionnaire that was used for assessing characteristics of regional building stock.

Appendix H describes the hazardous materials that are covered under SARA Title III, including their Chemical Abstracts Service (CAS) registry numbers, and the threshold quantities for reporting purposes.

Appendix I is a glossary of technical terms.

Appendix J has the steps for converting SHP Shake maps to Geodatabase with proper Projection and Schema.

Appendix K has the steps for converting SHP Hazard Data Maps to Geodatabase with proper Projection and Schema.

Appendix L shows how Aloha/Marplot can be run from within HAZUS and the results could be overlaid onto HAZUS inventory and results.

Appendix M shows how FLDWAV/FLOODVIEW can be run from within HAZUS and the results could be overlaid onto HAZUS inventory and results.

Appendix N shows how HAZUS can be configured to run with SQL Server 2005 and also how to configure HAZUS back to run with the MSDE based HAZUSPLUSSRVR installed by HAZUS installation.

Chapter 2. Installing and Starting HAZUS-MH MR3

2.1 System and Software Requirements

In order for HAZUS-MH MR3 to run properly, your system must meet certain minimum requirements. Table 2.1 Hardware and software requirements for provides guidance for three software operation levels. System requirements are directly related to the volume of data to be used in the analysis. For example, reasonable processing times can be expected when using the "Recommended" computer system if the software operator is analyzing multiple earthquake scenarios for large cities (population > 500,000). The operator is assumed to be working on an Intel PC.

Table 2.1 Hardware and software requirements for HAZUS-MH MR3.

	Minimal	Moderate	Recommended
Computer Speed Memory	Pentium® III 1 GHz core speed and 512 MB RAM Note: Allows moderately fast analysis of small communities only	Pentium® 4 2 GHz core speed and 512 MB RAM Note: Allows fast analysis of medium-sized communities and real-time analysis for small communities	Pentium® 4 with 800 MHz system bus and 2.6 GHz (or better) core speed and 1 GB RAM Note: Allows fast analysis of large urban areas and real-time analysis for all communities
Computer Storage: Free Hard Disk Space	10 GB Note: Allows installation of **HAZUS-MH MR3** and storage of three scenarios for a medium-sized community	40 GB Note: Allows installation of **HAZUS-MH MR3** and storage of three scenarios for large urban areas	80 GB Note: Allows installation of **HAZUS-MH MR3** and storage of 25 or more scenarios for large urban areas
Hardware Accessories	DVD-ROM reader with 12x minimum read speed Graphics Card with 1024x768 minimum resolution Mouse, Keyboard and 19" Monitor		
Supporting Software	Microsoft Windows 2000 Professional SP4 and Microsoft Windows XP SP2 (English Versions) ArcView 9.2 SP2 Spatial Analyst extension required with flood model. • HAZUS-MH installation will allow user to install HAZUS-MH on MS Windows 2000 and XP Service Packs higher than SP4 and SP2 respectively, but HAZUS-MH is not certified to work		

	flawlessly with those service packs.

ArcGIS can be purchased by contacting ESRI, Incorporated at 1-800-447-9778, or online at http://www.esri.com. ArcGIS and Windows products should be installed using the manufacturer's instructions.

Internet access is highly recommended, although not a system and software requirement. The **HAZUS** operator may occasionally need to access online Help, and current program status reports.

2.2 Installation

Before installing **HAZUS-MH MR3**, the minimum requirements listed in Section 2.1 should be met. If you are upgrading from HAZUS-99, read the section at the end of this chapter entitled "Upgrading from HAZUS-99 to **HAZUS**".

To install **HAZUS-MH MR3**, follow the steps outlined below.

1. Start Windows and log in with an account with Adminstrator rights.
2. Insert "**HAZUS-MH MR3 Applications DVD**" in your **DVD-ROM drive**. The setup will launch automatically.
3. If the setup does not launch automatically follow steps (4 and 5).
4. From the Windows **Start** menu select **Run...**. The following screen will appear.

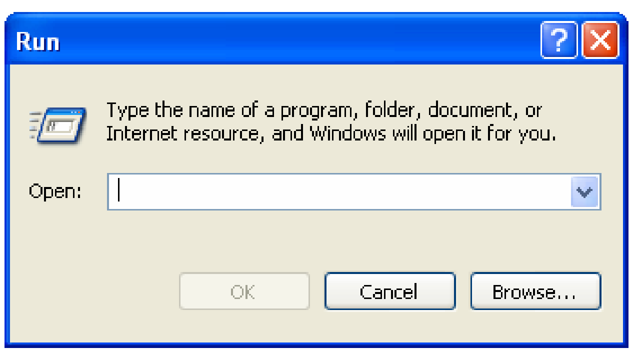


Figure 2.1 Run command dialog box.

5. To start the **HAZUS-MH MR3** setup program type ***x*:\setup** in the command line box as shown in Figure 2.1, where ***x*** is the DVD-ROM drive letter. Press Enter or click the **OK** key

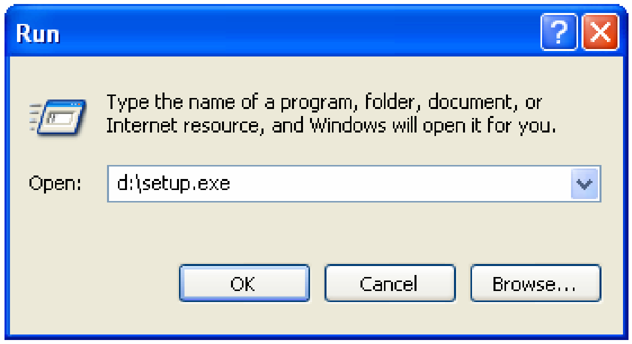


Figure 2.2 Start the HAZUS-MH MR3 setup program.

6. The setup program will appear. Click on the **Next** button.

Figure 2.3 Start of the HAZUS-MH MR3 installation program.

Figure 2.4 Register User Name and program permissions.

7. Permit program access to anyone who uses the computer or excude others from accessing **HAZUS** program and data. Enter your User Name and Company (or Agency) information. Select the appropriate installation choice for your study project. Then, click on the **Next** button.
8. Select the preferred type of installation shown in Figure 2.5 and Figure 2.6. Install the complete set of **HAZUS** modules (3 hazard modules, BIT, InCAST and FIT tools), the compact set (3 hazards, no tools), or select to customize your installation from one or more hazard and tool modules. Click on the **Next** button.

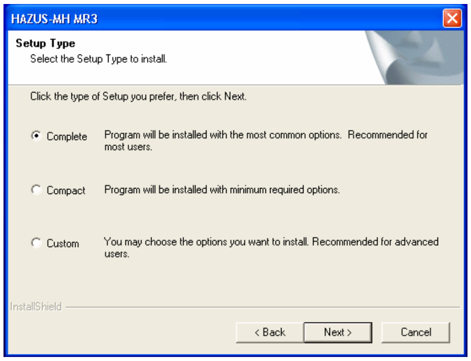


Figure 2.5 Complete installation.

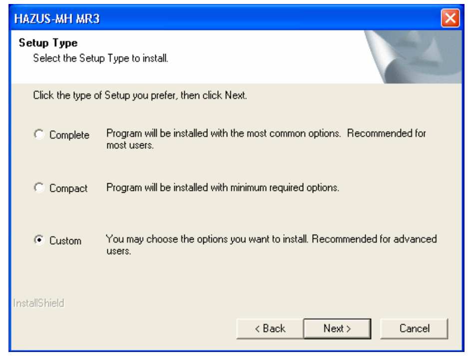


Figure 2.6 Custom installation.

9. Specify the directory where you wish **HAZUS** to be installed. The default directory is C:\Program files\HAZUS-MH, as shown in **Figure 2.7**. If you accept the default destination directory, click on the **Next** button.

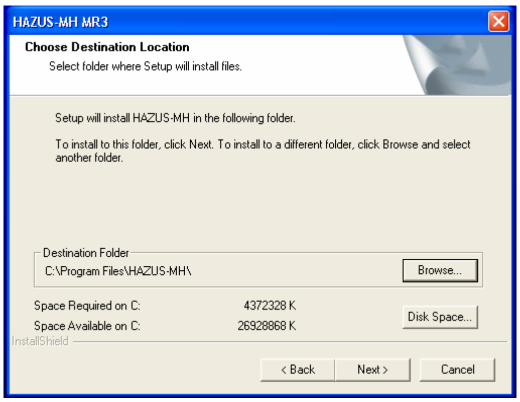


Figure 2.7 Specify the path of the HAZUS program directory.

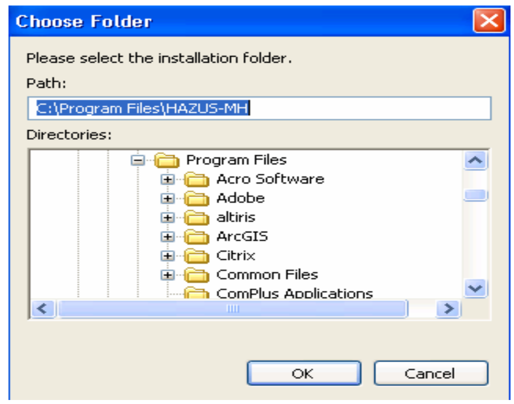


Figure 2.8 Specify the path of the HAZUS directory interactively.

Otherwise click on the **Browse** button and interactively choose a directory. The window will appear as shown in Figure 2.8.
You can select or type-in a new directory path and click on **OK**. You will be returned to the original "Select Installation Directory" window and the directory that you have selected will appear in the middle of the window. Click the **Next** button.

10. Folders will be created for the data files associated with your study regions. Specify the primary destination directory where you prefer HAZUS Region subfolders to be created. The default directory is C:\Program files\HAZUS-MH, as shown in Figure 2.9. If you accept the default destination directory, click on the **Next** button. Otherwise, click on the Browse button and interactively choose a directory. The "Select Destination Directory" will appear as shown in Figure 2.10.

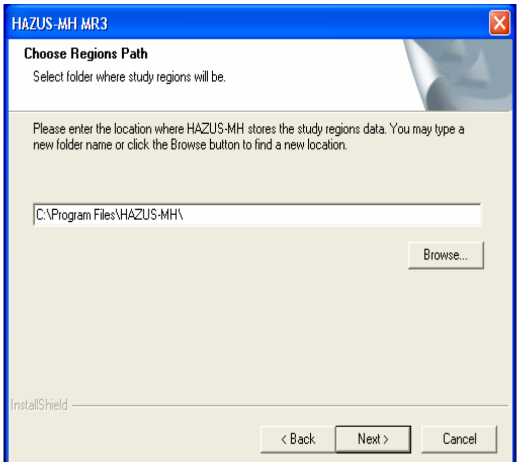


Figure 2.9 Default directory for Study Region files.

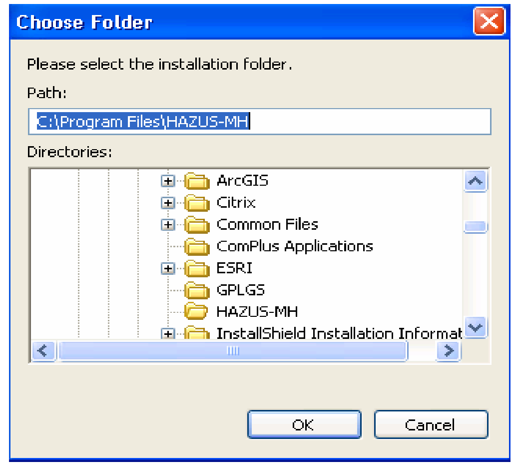


Figure 2.10 Create directory for Study Region files.

11. By defualt the DVD Drive is assumed to be the folder where the state data will be available for running HAZUS. If you want to use the State Data from a Network or Local drive then click on the Browse button as shown in Figure 11 below and select the folder where you would like to copy the State Data after installation. If you want to use the state data from the DVD then there is no need to make a change to the path on the dialog. Click on the next button to launch the next screen.

NOTE: The "Choose Data Path" dialog only specifies the folder where the state data will be copied by the user from the DVD after installation has completed. This dialog doesn't copy the data from the DVD to the specified folder; that has to be done manually by the user after installation.

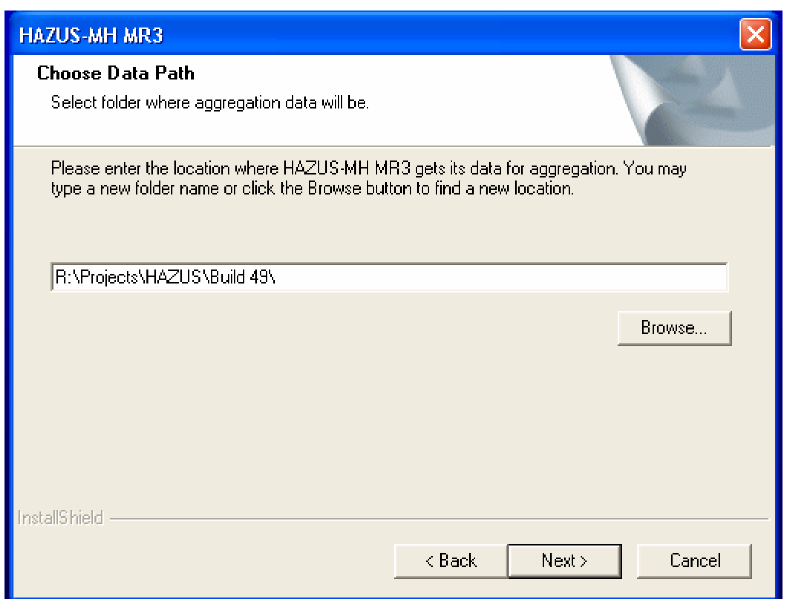


Figure 2.11 Set data path

12. If a custom installation was chosen, the next screen will offer a choice of program modules. One or more hazard modules must be selected (see Figure 2.12 Select each hazard module and tool program to install.).

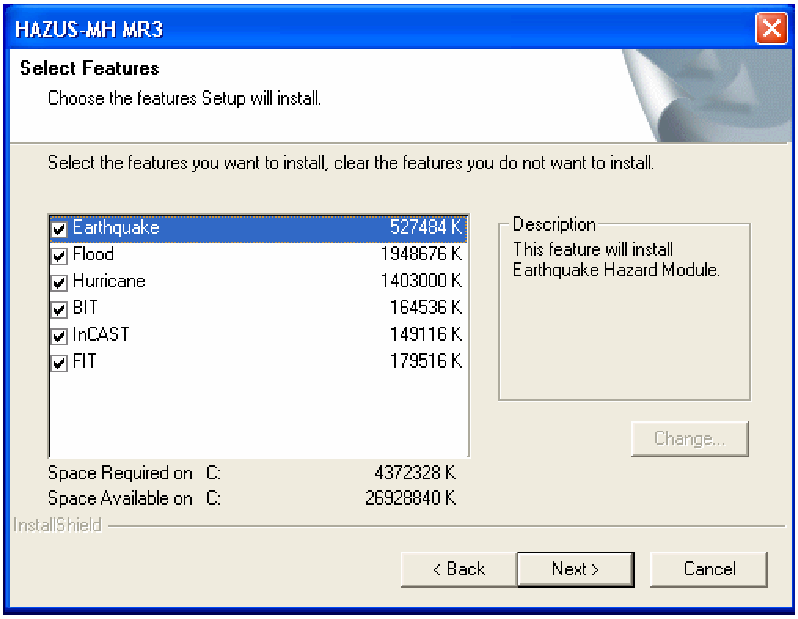


Figure 2.12 Select each hazard module and tool program to install.

Here is a brief description of the different components:

- **Earthquake** One of three natural hazard program components.
- **Flood** One of three natural hazard program components.
- **Hurricane** One of three natural hazard program components.
- **BIT** Converts custom data to **HAZUS** format (see Chapter 8)
- **InCAST** is a stand-alone tool to use for collecting inventory data in a format compatible with the **HAZUS** format.

13. Your next screen will show the installation option you selected and the directory paths you designate for the program, region data files, and data path. Figure 2.13 Complete installation settings. and Figure 2.14 Custom installation settings. show the screens that will display, depending on whether a complete or custom installation was chosen.

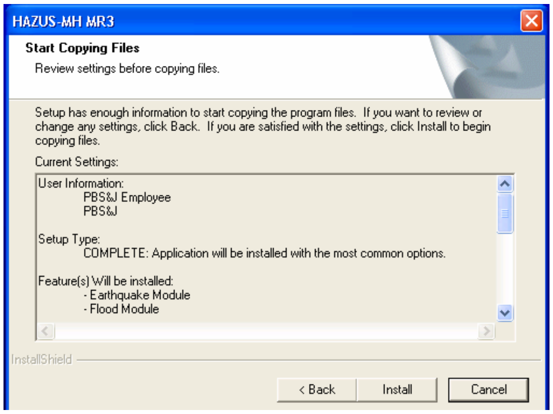


Figure 2.13 Complete installation settings.

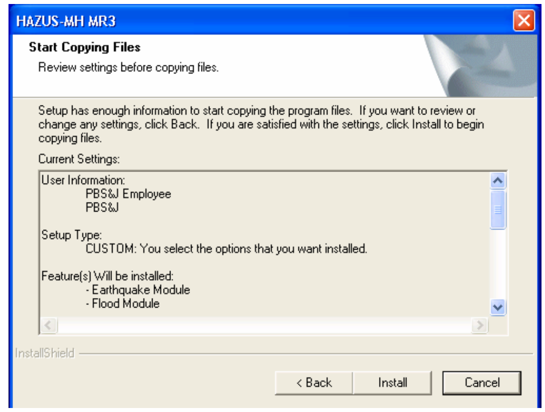


Figure 2.14 Custom installation settings.

Review the installation settings. Click on the **Back** button to go back to any of the previous windows and change the previous selections. If you are satisfied with your selection, click the **Install** button.

14. It will take five to ten minutes for the program to install. When the installation is complete the dialog box shown in Figure 2.15 Dialog box indicating successful HAZUS-MH MR3 installation. will appear and HAZUS program icon will automatically be created on your desktop. Click **Finish** to return to the Windows Setup. It is recommended that your restart your machine.

Figure 2.15 Dialog box indicating successful HAZUS-MH MR3 installation.

2.3 Upgrading from HAZUS99 to HAZUS

HAZUS is distinctly different than previous versions of the software. The program conforms to current GIS technology and the object-oriented data structure, or geodatabase. **HAZUS** functions inside of the ArcGIS environment and enhances its spatial analysis capabilities. Data used to calculate risk or loss, and data inventories must be in geodatabase format.

Geodatabases offer many advantages over previous GIS data structures, including a uniform repository for all feature types (i.e points, lines, and polygons), and more intellegent spatial relationships. **HAZUS** applies the newest GIS technology to improve loss estimation analysis and results.

Inventory data and study regions cannot be used directly in **HAZUS**. Individual inventories can be imported to a geodatabase; regions (i.e. HAZUS99 analysis regions) cannot. Re-run the loss estimation analysis in **HAZUS** to take advantage of the improved inventories, parameter values and model algorithms. See Chapter 5 for details on collecting inventory data.

2.4 Starting the Program

The installation program described in Section 2.2 creates a **HAZUS-MH** icon/shortcut on the computer's desktop. To start the program, double click on the **HAZUS-MH** icon, as shown in Figure 2.16.

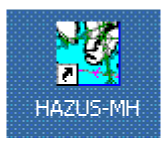


Figure 2.16 HAZUS-MH icon.

In order to enter inventory or run an analysis, you must first create a study region. Creating a study region is discussed in Section 3.1.

2.5 Uninstalling the Program

To uninstall **HAZUS-MH MR3**, launch Control Panel from **Start |Settings| Control Panel** as shown in Figure 2.17.

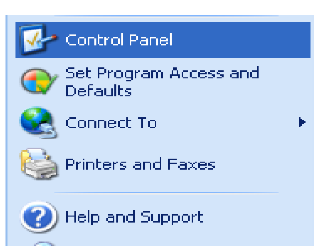


Figure 2.17 Open the Control Panel.

From the Control Panel window, double click on **Add/Remove Programs** as shown in Figure 2.18.

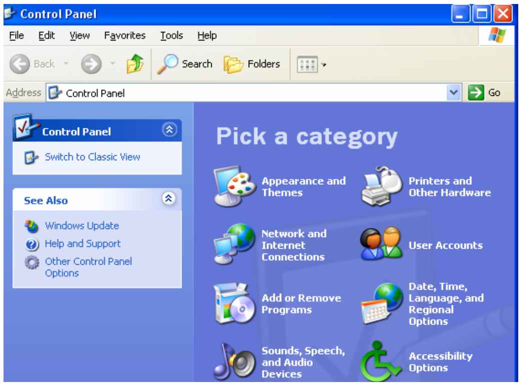


Figure 2.18 Select Add/Remove Programs.

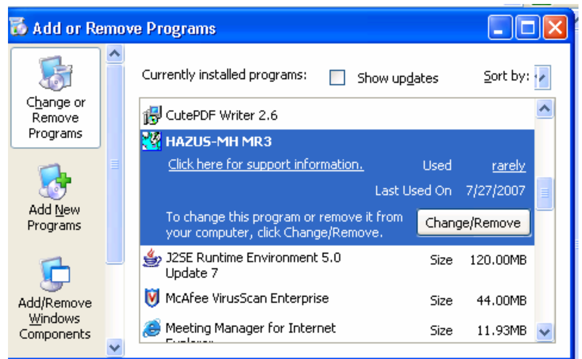


Figure 2.19 Uninstall HAZUS-MH MR3.

You will be prompted with an **Add/Remove Program Properties** window as shown in Figure 2.19. Highlight **HAZUS-MH** and double click on the **Change/Remove** button. The install wizard will start and provide you with three uninstall options shown in Figure 2.20 : Modify your previous installation (ex. Add tools), Repair (reinstall) program components, or Remove all of the previously installed **HAZUS-MH MR3** files.

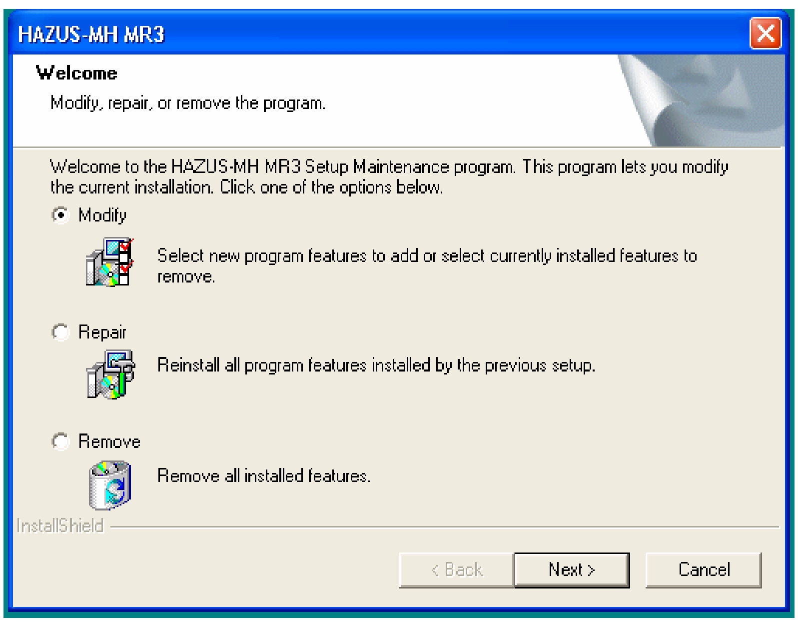


Figure 2.20 Modify, Repair, or Remove the HAZUS-MH MR3 program.

2.6 Program Basics

HAZUS is an ArcGIS-based program with a standard Windows interface that provides a familiar working environment. Unlike the previous versions, **HAZUS** resides on top of ArcMap. The only ArcMap function that has been disabled is table loading. Buttons are added to the ArcMap menu bar to perform **HAZUS** hazard risk analysis and loss modeling functions (see Figure 2.21).

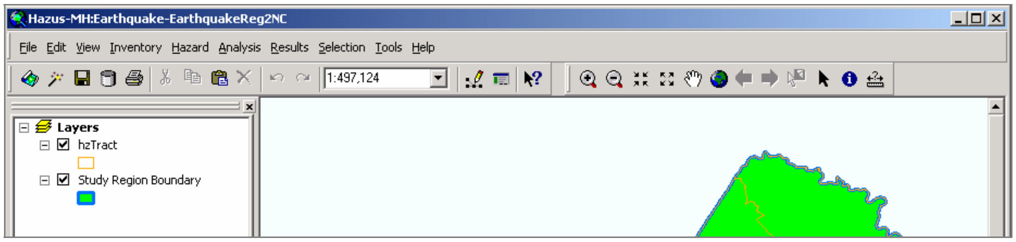


Figure 2.21 HAZUS menu bar adds functions to ArcMap.

The user interface is comprised of a menu bar, tool bar and various screens and windows. These elements follow standard Windows conventions and allow you to manipulate and analyse data within **HAZUS**. This section briefly describes some of the features.

2.6.1 Menu Bar

Functional menus appear alongside the general ArcMap menus: Inventory (Figure 2.22), Hazard (Figure 2.23), Analysis (Figure 2.24), and Results (Figure 2.25). The menu bar is displayed at the top of the screen. **Bold** menu items indicate that the items are available; grayed out menu items are not available. The menus marked with a (*) as described in Table 2.2 below are the menus added by HAZUS to the ArcMap menu.

Table 2.2 HAZUS menu items

File	Execute standard software actions such as open table, save and print.
Edit	Edit text and features including cut, copy, and paste.
View	View data and map display. Zoom in or out. Show the geodatabase Table of Contents.
Inventory *	Add, modify, delete and copy inventory information.
Hazard*	Select hazard maps and the scenario event you wish to work with.
Analysis*	Modify the analysis data, parameters and assumptions.
Results*	Used to view and map analysis results.
Insert	Customize the layout view.
Selection	Locate multiple inventory items based on criteria you provide, and search for specific record information.
Tools	Basic GIS utilities menu.

Help	Help files are available for ArcGIS only. Help files for **HAZUS** are not available in the current version, due to budget constraints.

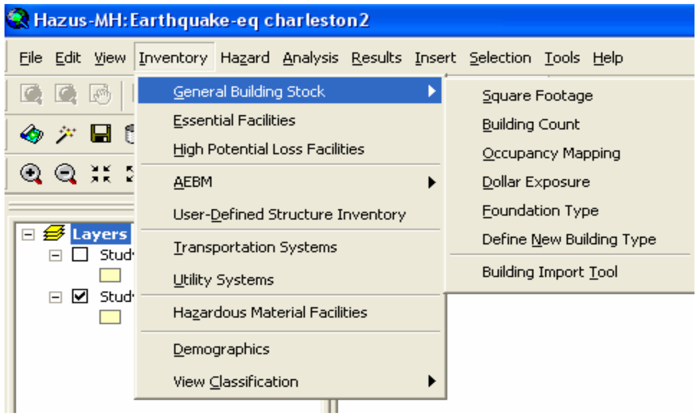


Figure 2.22 HAZUS Inventory menu.

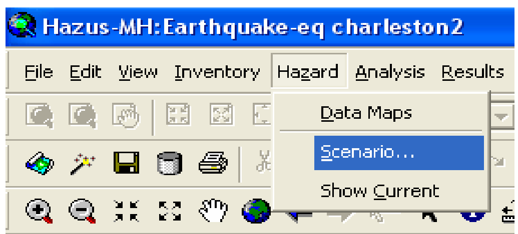


Figure 2.23 HAZUS Hazard menu.

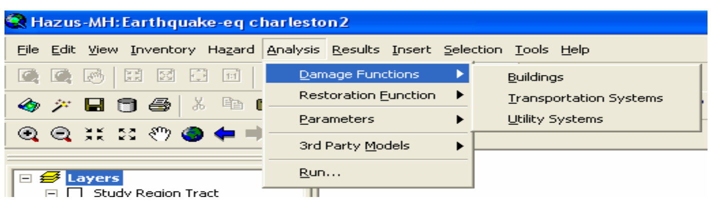


Figure 2.24 HAZUS Analysis menu.

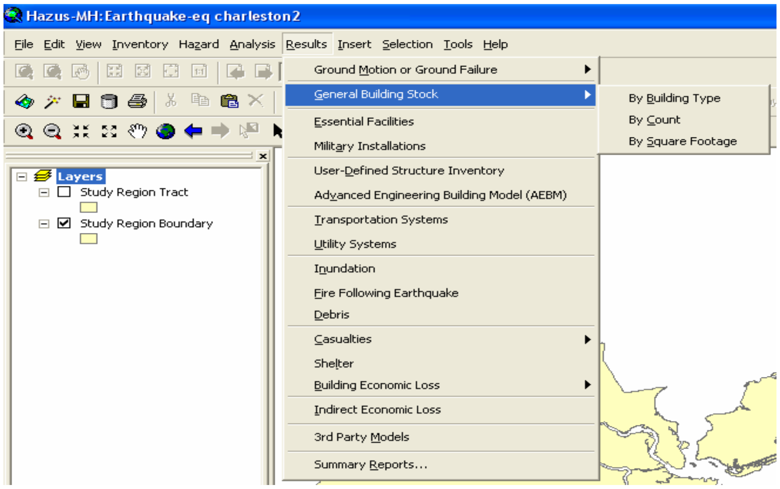


Figure 2.25 HAZUS Results menu.

2.6.2 Tool Bar

A Tool bar is a set of buttons that execute commands by clicking on them. The standard **HAZUS** tool bar appears under the menu bar. The tool bar buttons are used for object selection, zooming in or out, moving around maps, obtaining information, measuring distance and creating points. Details of the ArcMap toolbars can be found in the ArcGIS Help Manual. **Bold** buttons indicate that the buttons are available; grayed out buttons are not available. **HAZUS** adds two tools to the ArcGIS toolbar shown in Figure 2.26. The first tool button accesses the startup dialogue for selection, importing, or creation of an analysis study region. The wand tool allows switching among the hazard types (earthquake, flood, hurricane) the user has loaded.

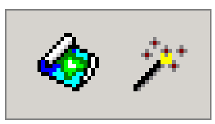


Figure 2.26 HAZUS additions to the toolbar.

2.7 Limitations of use for Earthquake Model

Region size and analysis time

S.No	Region Size	Aggregation Time	Analysis Time (Select All Without Contours)	Analysis Time (Rapid Assessment)
1	150 Tracts	6 Minutes	10 Minutes	7 Minutes

2	500 Tracts	7 Minutes	30 Minutes	20 Minutes
3	2000 Tracts	30 Minutes	2 Hours	1 Hour 30 Minutes

Rapid assessment excludes the following modules: Damage by Building Count, All HPLF, AEBM, User Define Structures, All Transportation except Highways roads and bridges and Airports, All Utilities except Potable water and electric power system performance, Inundation, Contours

Virtual Memory:

S.No	Region Size	Min Virtual Memory (Scenario other than AAL)	Min Virtual Memory (Scenario AAL – Eq Only)
1	150 Tracts	328 MB	512MB
2	500 Tracts	512MB	848MB
3	2000 Tracts	1024MB	2048MB

The user can expect the following limitations in using the Earthquake Model.

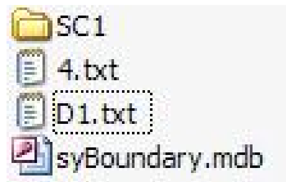
1. SQL Server 2005 Express has a size limit of 4 GB per database, which affects the size of the region you can analyze. The data for the 3 hazards share the 4 GB limit. To work-around the 4 GB database limit, the full version of Microsoft SQL Server 2005 must be used. Refer to Appendix N of Users Manual for details.

2. Many functions take a long time to run. Study region aggregation can be speeded up by copying the database to the local hard-disk. If necessary, the Registry can be updated so that HAZUS looks to the location where you copied the data on the local hard disk rather than to the default DVD location.

   The HAZUS installation allows the user to specify the folder where the state data will be copied through the "Choose Data Path" dialog in the installation wizard. If, at the time of installation, the user specifies the folder where the data will be copied after installation, they only need to perform Step a) as described below. If at the time of installation the user does not specify the folder where the state data will be copied by the user after installation, or if they want to change the folder specified during installation, then Steps b) through e) for updating the Registry should also be completed.

   NOTE: The "Choose Data Path" dialog in the installation process only specifies the folder where the state data will be copied by the user from the DVD after installation has completed. This dialog doesn't copy the data from the DVD to the specified folder; that has to be done manually by the user after installation.

a) Copy one or more of the state data folders (e.g., NC1), both the DVD identification files (e.g., D1.txt ^ 4.txt) and "syBoundary.mdb" from the Data DVD to a folder on your hard drive (e.g., D:\HAZUSData\). As an example, the following graphic illustrates how the data for the state of South Carolina would be organized under the HAZUSData folder.



b) Next, point the program to the data folder on your local hard drive. To do this, click the "Start" button and select "Run" to open the Run window. Type "regedit" in the Run window edit box and click the "OK" button to open the Registry Editor. Navigate through the folders listed in the Registry Editor to the following location:

HKEY_LOCAL MACHINE | SOFTWARE | FEMA | HAZUS-MH | General

c) Now look at the right side of the window and find the entry called "DataPath1". Double click on "DataPath1" to open the Edit String window and enter the full name of the folder on the hard drive that contains the data copied from the DVDs in the edit box. Click the OK button to update the DataPath1 value.

d) IMPORTANT: Make sure the path ends with a "\" and do not change any of the other registry settings.

e) Close the Registry Editor by choosing Exit from the File menu of the Registry Editor.

3. Components of independently developed data sets might not line up on maps, for example, the placement of bridges and roads, and facilities.

4. Inventory data and subsequently the Level 1 analysis functionality is unavailable for the US held territories.

Freeing memory using SQL Server Manager

SQL Server can often lock memory as a working set. Because memory is locked, HAZUS or other applications might receive out of memory errors or run slower. To work around this problem, restart the SQL Server service as follows:

1. Restart your computer by clicking **Start,** and then click **Shut Down.** In the "**What do you want the computer to do?"** list, click **Restart.** NOTE: Restarting will close all open applications, so be sure to save your work before choosing to re-start.

2. Restart SQL Server using the SQL Service Manager. Use the following process to open SQL Server Service Manager (SQL SSM) and restart the service:

   a. Close HAZUS and related applications (BIT and InCAST), if they are running.

   b. Open a Command window (Start | Run | Cmd)

   c. Type NET STOP MSSQL$HAZUSPLUSSRVR and hit Enter. You shoud see a meesage about the service stopped successfully.

   d. Type NET START MSSQL$HAZUSPLUSSRVR and hit Enter. You should see a message about the service started successfully.

   e. Close the Command window by typing Exit

   f.

Increasing Virtual Memory to Run Large Study Regions

An "out of memory" error might occur when running a earthquake analysis when region size is more than 1000 census tracts. This occurs if the current page file size is not enough to carry out updates to the SQL server database. To work around this problem increase the page file size. The process (in Windows 2000. See page ix for instructions in Windows XP) is as follows :

1. Open the control panel folder and locate the system icon. To open the control panel, click on **Start**, point to **Settings**, and then click **Control Panel**.

2. Double-click the system icon to open the **System Properties** dialog (shown in Figure 2.27).

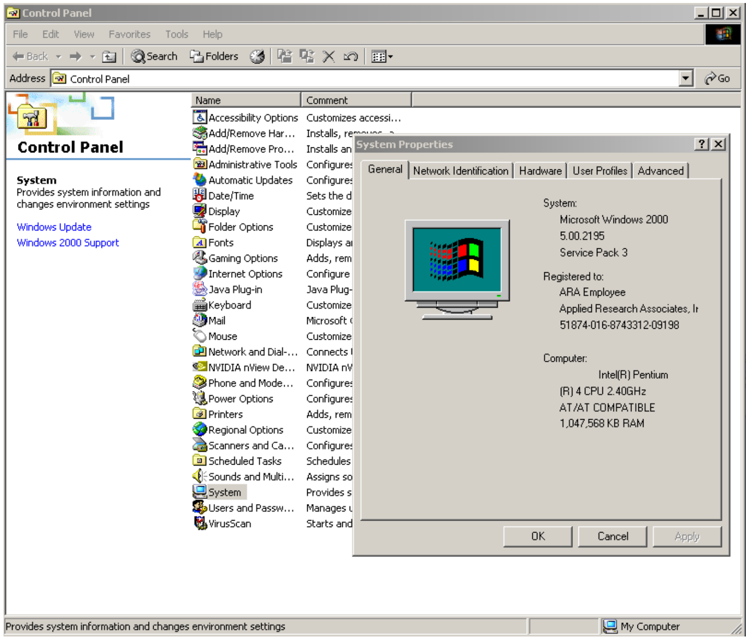


Figure 2.27 Control Panel folder and the System Properties dialog

3. On the **Advanced** tab, click **Performance Options**, and under **Virtual memory**, click **Change**. (Figure 2.28 through Figure 2.29)

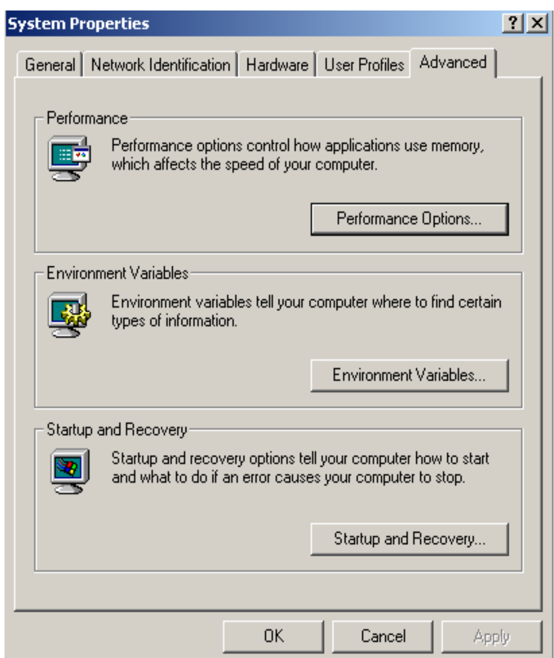


Figure 2.28 Advanced page on the System properties dialog

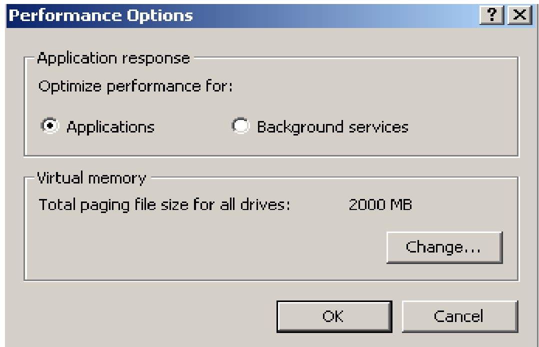


Figure 2.29 Performance Options Dialog

4. In the **Drive** list, click the drive that contains the paging file you want to change. (Figure 2.30)

5. Under **Paging file size for selected drive**, type a new paging file size in megabytes in the **Initial size (MB)** or **Maximum size (MB)** box, and then click **Set**. (Figure 2.30)

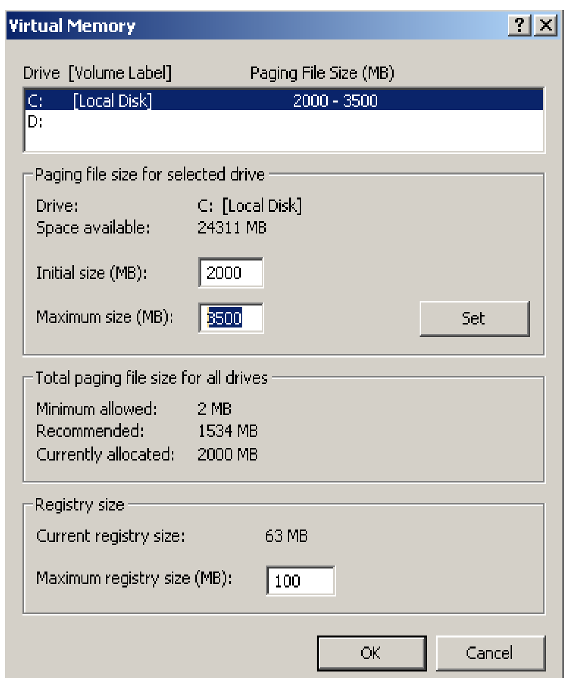


Figure 2.30 Virtual memory settings

For best performance, set the initial size to not less than the recommended size under **Total paging file size for all drives**. The recommended size is equivalent to 1.5 times the amount of RAM on your system. If you cannot change the file size or cannot resolve the “out-of memory” error by increasing the page file size, consider creating smaller regions (each with less than 1000 census tracts or blocks).

Chapter 3. Running HAZUS with Default Data

HAZUS contains a variety of default parameters and databases. You can run a loss estimation analysis using only default data, but your results will be subject to a great deal of uncertainty. Default data supplied with **HAZUS** are described in Section 3.9. If you wish to reduce the uncertainty associated with your results, you can augment or replace the default information with improved data collected for your region of study. This chapter will guide you through a very simple analysis using only default data. For more detailed information about collecting and entering additional data, or modifying default parameters and data, see Chapters 4 through 8.

Before running a loss estimation analysis you must define a study region. *The Study Region*, in **HAZUS** terminology, is the geographic unit for which data are aggregated, the earthquake hazard defined, and the analysis carried out. **HAZUS** will prompt the user to create a new region or import a previously created region. You can also open, delete, duplicate, backup, or export an existing region.

3.1 Creating the Study Region

The study region can be any combination of states, counties, cities, census tracts, or census blocks. The study region you define will depend upon the purpose of the loss study. In many cases the region will follow political boundaries such as city or county limits. If you are performing a study for a particular city, then the region may include only the area within the city limits. On the other hand, if you are looking at an entire metropolitan area the region may consist of several counties. Defining the study region requires only that you be able to identify the census tracts that comprise the region.

However, it is important to note that **HAZUS** will not include any site-specific inventory data that you have defined outside the region. In fact, if you include facilities that are located outside the defined study region, **HAZUS** will automatically eliminate these facilities from the inventory databases. The region will always be defined by a census tract boundary, within which population, demographics, and general building stock values are aggregated. The user can only define a study area that intersects U.S. census tract boundaries by gridding the census tracts involved into smaller units.

The earthquake methodology is based upon using census tracts as the smallest geographic unit. Census tracts are divisions of land that are designed to contain 2,500 to 8,000 inhabitants with relatively homogeneous population characteristics, economic status and living conditions. For this reason the physical area within census tracts will vary depending on the density of the population. In densely populated regions census tracts can be a few city blocks, whereas in rural areas a census tract may be many square miles.

Census tract divisions and boundaries change only once every ten years. Census tract boundaries never cross county boundaries; hence census tracts can completely and uniquely define all the area within a county. This characteristic allows for a unique division of land from country to state to county to census tract. Note, however, that a census tract can cross city boundaries. A unique 11-digit number identifies census tracts.

The first two digits represent the tract's state; the next three digits represent the tract's county, while the last six digits represent a number that identifies the tract within the county. For example, a census tract numbered 10050505800 would be located in Delaware (10) in Sussex County (050).

You have the flexibility to define any arbitrary study region by selecting a set of census tracts. The study region may overlap multiple states and counties and may contain only portions of counties or cities. You can define any number of study regions (limited only by disk space), and can switch between them at any time. The steps to defining the study region are to 1) name the study region, 2) select the state or states, 3) select counties, and 4) select census tracts. Users can also choose to define the aggregation area by developing a customized gridding method for use with the loss estimation model until a standardized method bexomes available.

Figure 3.1 displays the first dialogue box that appears when **HAZUS** is launched. Only valid selections will appear in bold type. In order to create a new study region the one of the six State Data DVDs must be accessible. Select to **Create a new region** and click on the **OK** button.

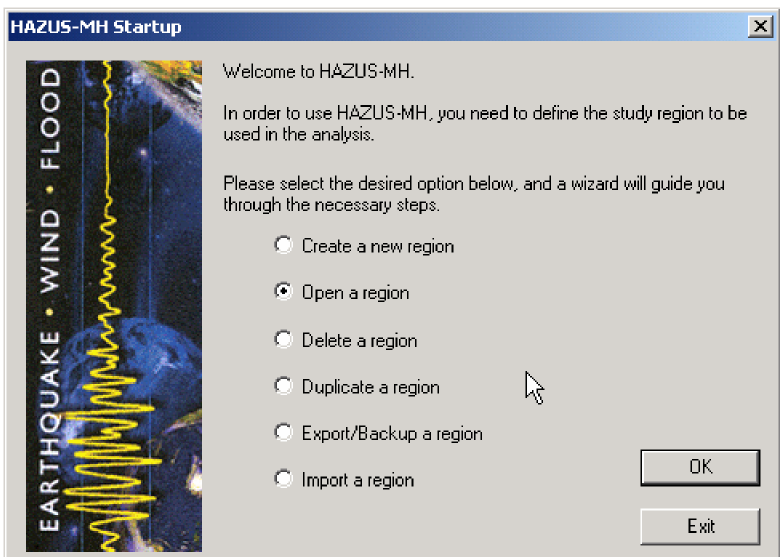


Figure 3.1 HAZUS startup dialogue.

The wizard will present the following dialogue windows to guide you through the steps for creating a region**.** Figure 3.2 prompts the user for a region name and description.

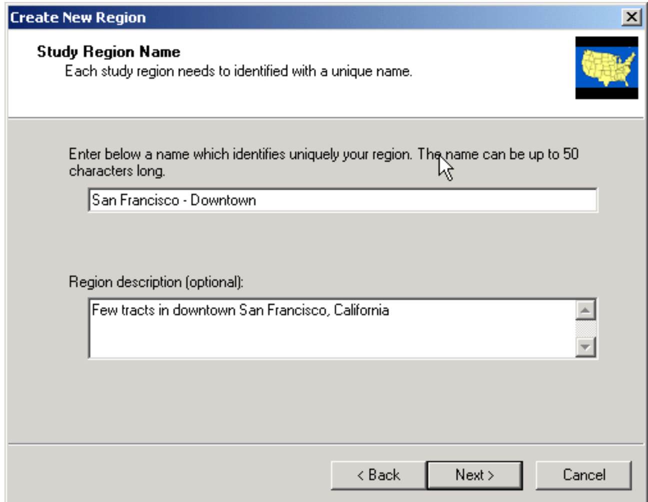


Figure 3.2 Name the new study region and enter a description.

Next, you will be asked to select one or more hazard types to analyze (see Figure 3.3). Only hazard modules that have been installed will be available for selection. The hazards selected here will be the ones that may be used for analysis of this particular study region. The user cannot add another hazard to this region after it has been created, but can create a similar study region with different hazards.

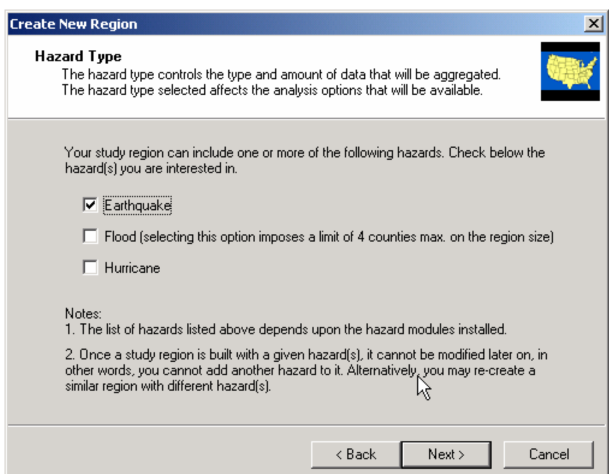


Figure 3.3 Hazard type for new study region analysis.

Select an aggregation level: state, county, or census tract. Census tract is the smallest allowable unit for analysis, and the level at which population and general building stock values will be aggregated for estimating losses (see Figure 3.4).

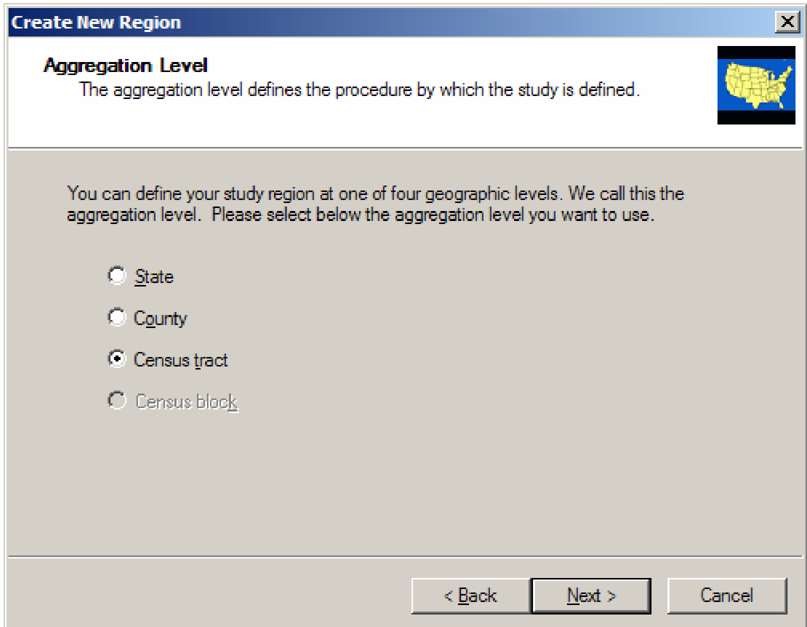


Figure 3.4 Aggregation level for analysis.

Select which states are included in the study region[1]. To select a state, click on the name of that state. To select multiple states, hold down the <**Ctrl**> key while you click on all of the states you wish to include. The user has selected California in the example shown in Figure 3.5 below. Alternatively you can click the **Map** button and choose the states from a map, as shown in Figure 3.6 below. To select multiple states, hold down the **Shift** key while clicking on the desired states. When finished, press **Selection Done** button.

[1] When clicking ‘Next’ from the ‘Aggregation Level’, HAZUS-MH will look for the boundary file to start the aggregation selection process. Insert the one of the six State Data DVDs’ to continue.

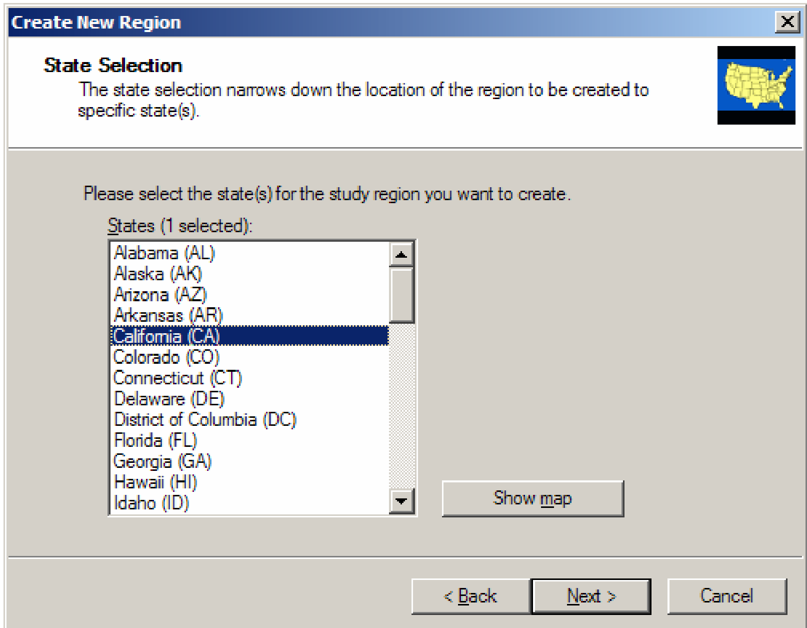


Figure 3.5 State selection from list.

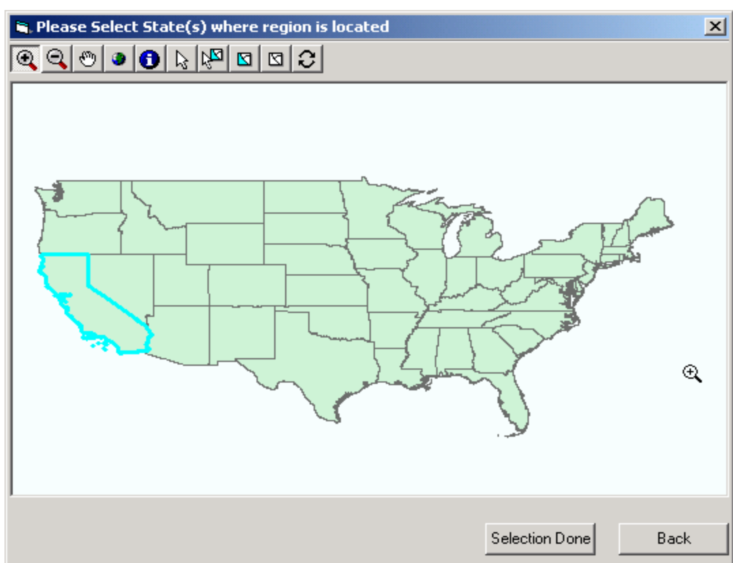


Figure 3.6 State Selection from map.

It is important to make sure that you have enough disk space before you start the aggregation as per the requirements given in Table 2.1 in the previous chapter. When you have finished selecting the state(s), click on the **Next** > button.

Select the counties you wish to include in the study region by clicking on the names of those counties. Multiple counties can be selected by holding down the <**Ctrl**> key and clicking on the desired counties as shown in Figure 3.5. Alternatively you can click the **Map** button and choose the counties from a map of the state as shown in Figure 3.6. When finished, press **Selection Done** button.

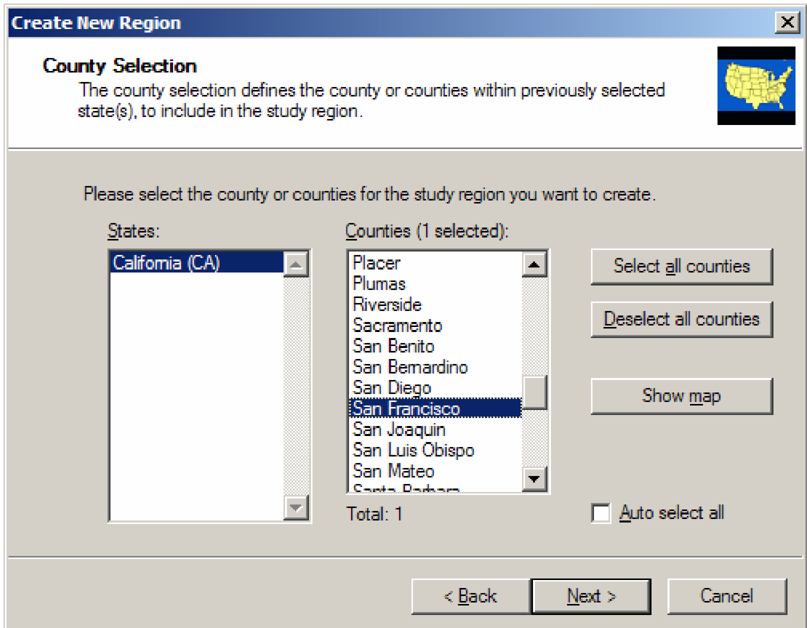


Figure 3.5 County selection from list.

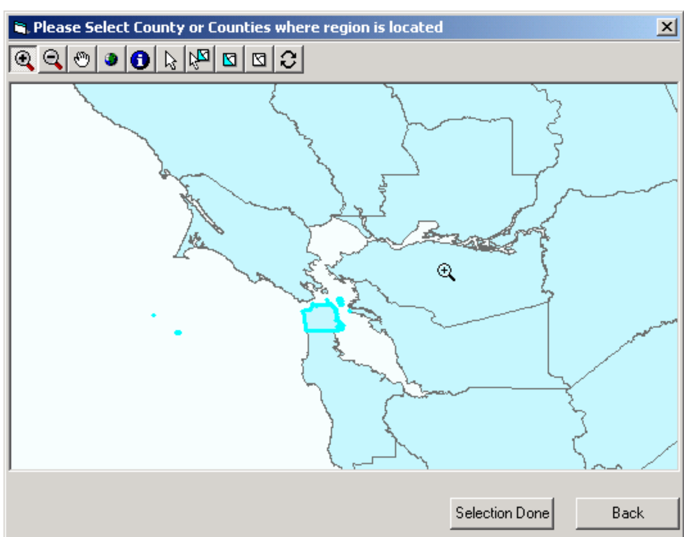


Figure 3.6 County selection from map.

Once you have selected the counties and clicked on the **Next>** button, you will be presented with a list all of the census tracts in the selected counties as shown in Figure 3.7. You can then select the census tracts that define the study region from the list, or from the map (see Figure 3.8). At any point in this process you can undo your selections by using the **<Back** button.

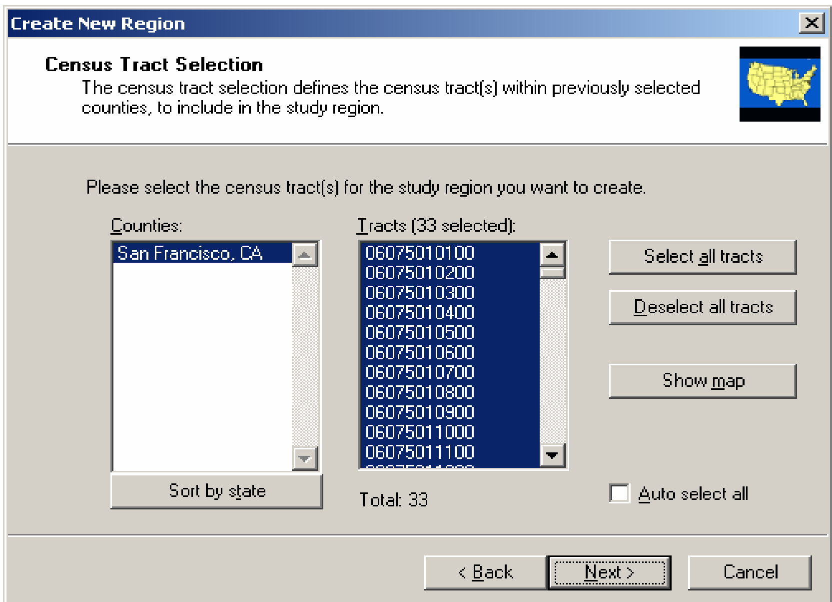


Figure 3.7 Census tracts selection from list

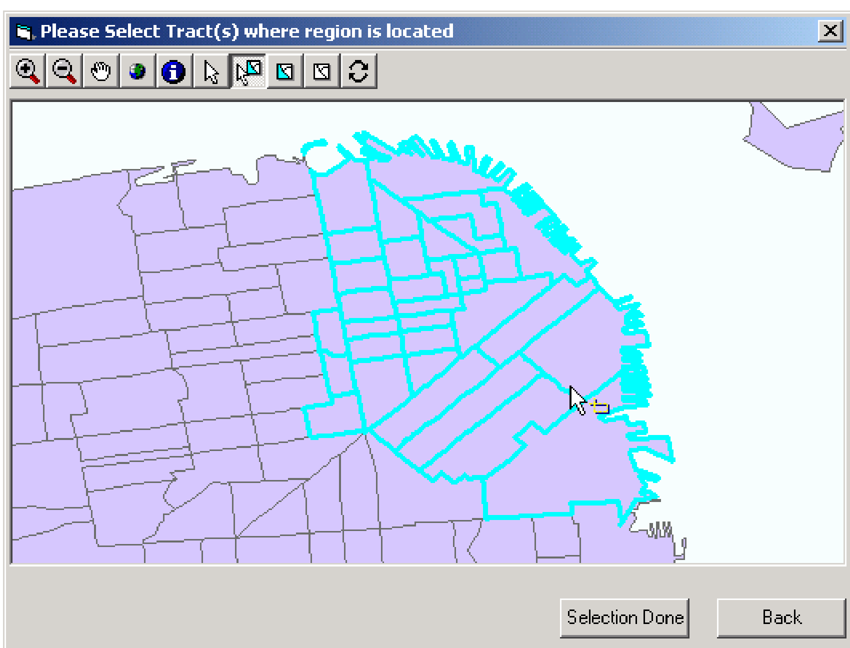


Figure 3.8 Census tracts selection from map.

The census tracts do not have to have continuous numbering, nor do they need to be contiguous. As with the other windows you may graphically select census tracts by using the **Map** button. The selection of census tracts directly from the map is helpful when choosing census tracts that are in the vicinity of a city yet not in a numerical sequence; or for the case when the location of a city is known while the census tract numbers around that city are not known.

When you have selected the census tracts, click on the **Finish** button. A processing status window will indicate the progress of aggregation. You will be prompted to load a DVD containing the default inventory data for your state of interest if the DVD inserted at the start of the study region creation process is not having your state of interst. The default inventories have greater uncertainties associated with them, but can be used for a baseline analysis. Replacement of the default data with improved inventories is discussed in Chapter 6. Move directly to Section 3.5 if you have successfully created your new study region.

3.2 Importing a Study Region

Study regions that have been previously created and exported may be imported. At the startup dialogue window, click in the radio button to select **Import a region** and press the **OK** button (see Figure 3.9).

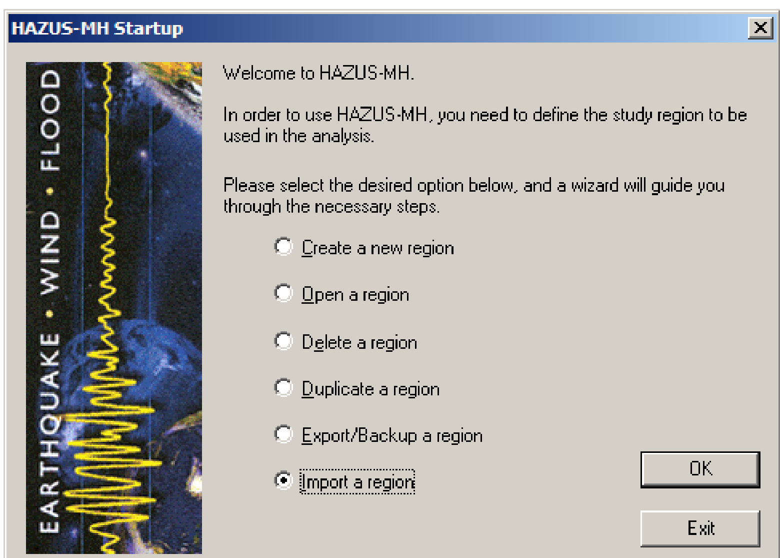


Figure 3.9 Import a study region.

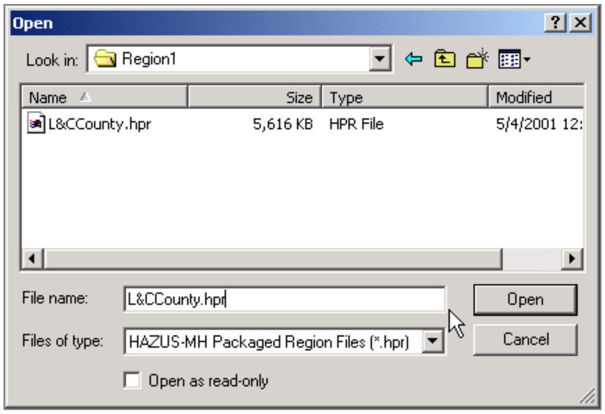


Figure 3.10 Select a previously created study region.

The default directory for region files will appear with any available files to import. The file suffix, ***.hpr** indicates the file has been packaged and exported. Make sure you are where the established region file exists, highlight the file, and select it to open the region from the list of available files (see Figure 3.10). Remember: **HAZUS** uses a new data structure. Region files are no longer fully-independent folders with data and analysis results. You can only import those regions created with **HAZUS**.

Region files may be chosen from the list in the dialogue window whenever opening, deleting, duplicating, exporting, or importing. In each case, file information will be shown for the unique regions: name, description, date created, date last accessed, applied hazard(s), region identifier, and validity status[2]. The particular function can only be applied to the regions listed.

3.3 Opening a Study Region

The startup **HAZUS** dialogue window also includes the option to open an existing region. If a valid study region is available as in Figure 3.11, you can select it by the name and description it was given when the region was created.

[2] A valid region has a valid value of 1 (true). An invalid region has valid value of 0 (false). An invalid region is the result of an aggregation process that did not complete successfully.

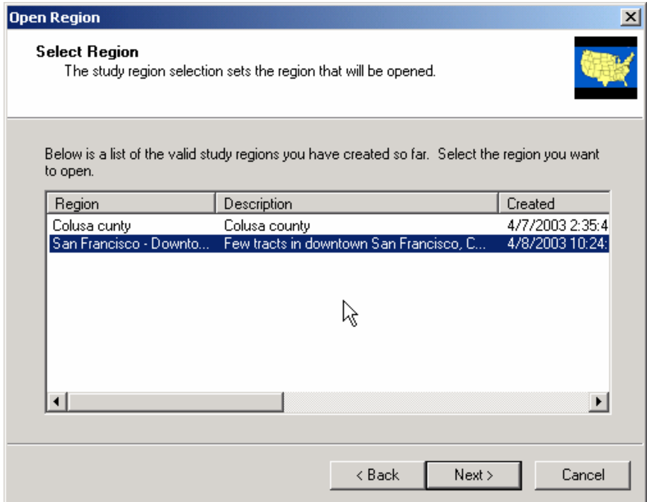


Figure 3.11 Open a study region.

Click 'Finish' at the 'Completing the Open Region Wizard' to open the selected region as showin in Figure 3.12.

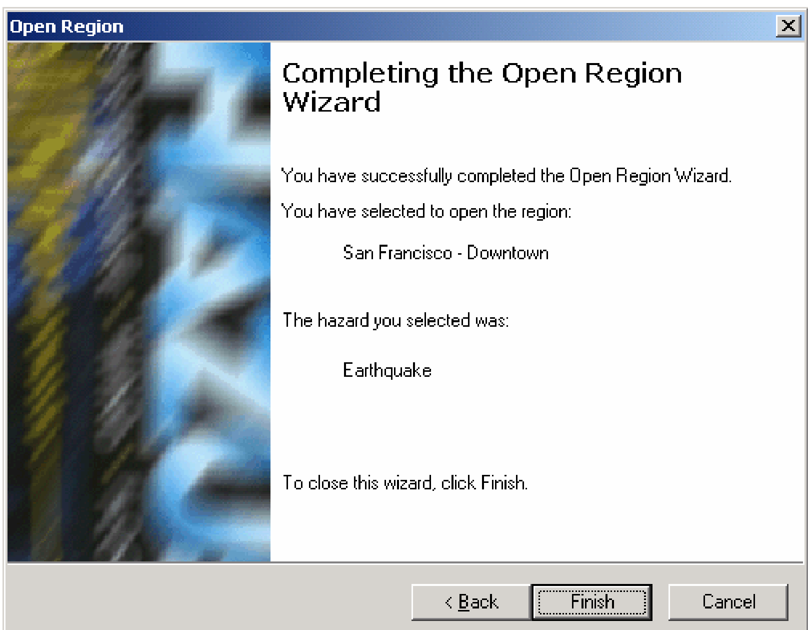


Figure 3.12 Completing the Open Region Wizard Dialog.

3.4 Deleting and Duplicating a Study Region

Regions can be deleted, duplicated, and backed up from the same **HAZUS** startup menu. The user is given the choice to select among the valid regions. If no valid regions exist to be acted upon, the selection on the startup window will not be available. The user will be warned before a serious data loss might occur, as in Figure 3.13 .

Figure 3.13 Deletion of a study region is permanent.

3.5 New Study Region

The first DVD (called the Applications DVD) provided with **HAZUS** contains the program and boundary files and Installation Verification Data. Additional DVDs include default inventory data to be used for your study region. When the new region is complete, the user will confirm the processing is finished. An ArcMap interface will appear displaying the new region (see Figure 3.14).

The map displayed will have one or more layers, depending on the aggregation level chosen. For example, if an entire state equals the study region and the aggregation level is equal to census tract, two boundary layers will be listed for display in the Table of Contents (TOCs): one polygon representing the entire region, and one layer of all the census tracts within the study region. County boundaries (and other boundary layers) can be added by highlighting **Layers** in the TOC and right-clicking the mouse. Select the "+" sign to add more data layers.

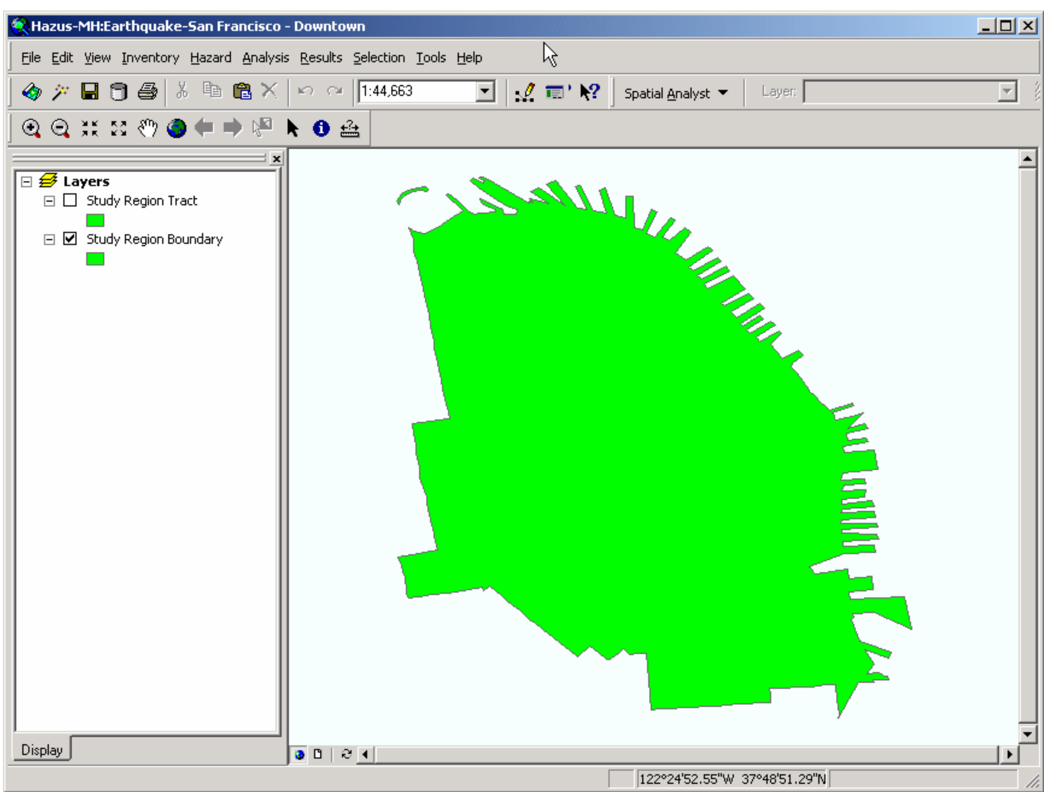


Figure 3.14 Map of a study region.

The software operator will see the four **HAZUS** menus and two buttons added to the graphic interface. All ArcMap and ArcView functions are available, i.e. view properties of each data layer. The operator can edit the feature symbols to distinguish the data layers, as in Figure 3.14.

The remaining default inventory extracted from the DVD for the study region can be displayed. Select the **Inventory** menu to display the study region data including building stock, hospitals, transportation, utilities, and hazardous materials (see Figure 3.15).

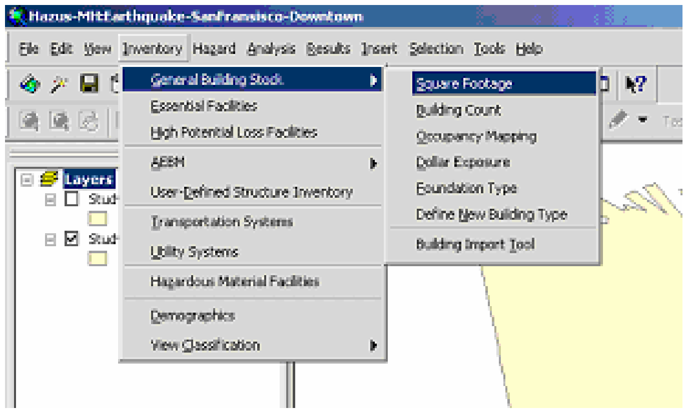
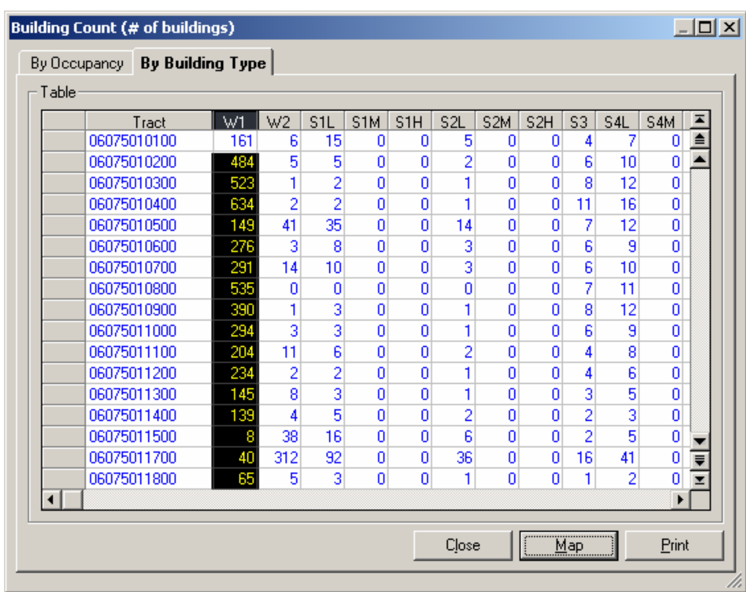


Figure 3.15 HAZUS Inventory menu.

Inventories are viewable in tabular format, and in many cases can also be mapped. Figure 3.16 and Figure 3.17 show default data available for our sample study region (downtown San Francisco). The number of wood buildings are shown as aggregated by census tract (i.e. general building stock class), and highways and hospitals are overlayed.



Tract	W1	W2	S1L	S1M	S1H	S2L	S2M	S2H	S3	S4L	S4M
06075010100	161	6	15	0	0	5	0	0	4	7	0
06075010200	484	5	5	0	0	2	0	0	6	10	0
06075010300	523	1	2	0	0	1	0	0	8	12	0
06075010400	634	2	2	0	0	1	0	0	11	16	0
06075010500	149	41	35	0	0	14	0	0	7	12	0
06075010600	276	3	8	0	0	3	0	0	6	9	0
06075010700	291	14	10	0	0	3	0	0	6	10	0
06075010800	535	0	0	0	0	0	0	0	7	11	0
06075010900	390	1	3	0	0	1	0	0	8	12	0
06075011000	294	3	3	0	0	1	0	0	6	9	0
06075011100	204	11	6	0	0	2	0	0	4	8	0
06075011200	234	2	2	0	0	1	0	0	4	6	0
06075011300	145	8	3	0	0	1	0	0	3	5	0
06075011400	139	4	5	0	0	2	0	0	2	3	0
06075011500	8	38	16	0	0	6	0	0	2	5	0
06075011700	40	312	92	0	0	36	0	0	16	41	0
06075011800	65	5	3	0	0	1	0	0	1	2	0

Figure 3.16 Default building stock data inventory.

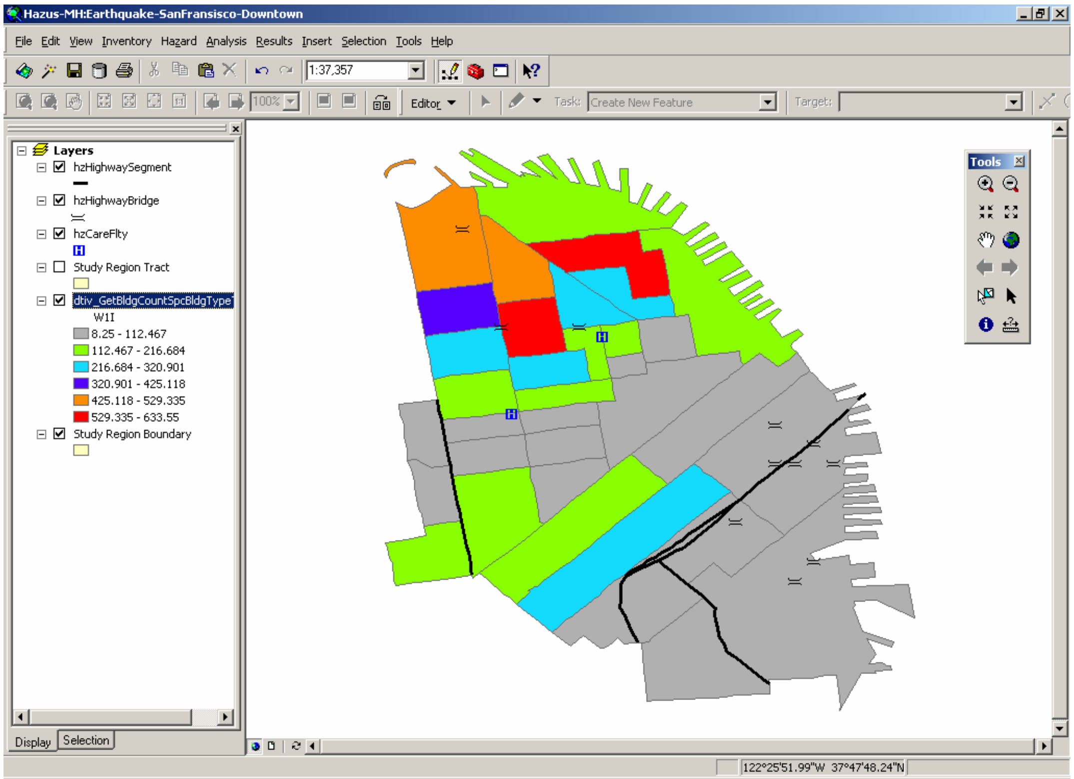


Figure 3.17 Default inventory data for study region.

3.6 Defining a Scenario Earthquake

Before an analysis can be run, you must quantify the potential earth science hazards (PESH) that will serve as a basis for evaluating damage and losses. For an earthquake loss analysis, this involves identifying the size and location of the earthquake and estimating its associated ground motions and ground deformations due to ground failure. For this methodology, ground deformations due to liquefaction, landslides, and surface fault rupture can be included.

While there are a number of options available for defining PESH (see Section 9.1), the only method described in this section is defining a scenario earthquake using the arbitrary event option.

Click on the **Hazard** menu as shown in Figure 3.18. Clicking on the **Scenario** option allows you to define the earthquake hazard using the window shown in Figure 3.19.

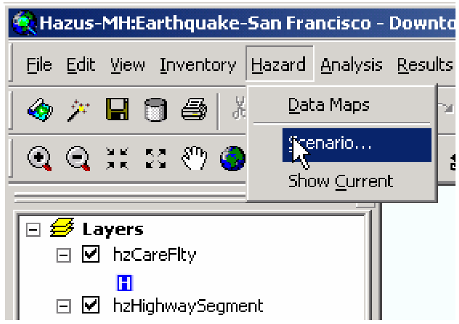


Figure 3.18 Hazard definition menu in HAZUS.

The scenario definition wizard will appear for entering a new event. Select to define a new scenario, and press **Next** >.

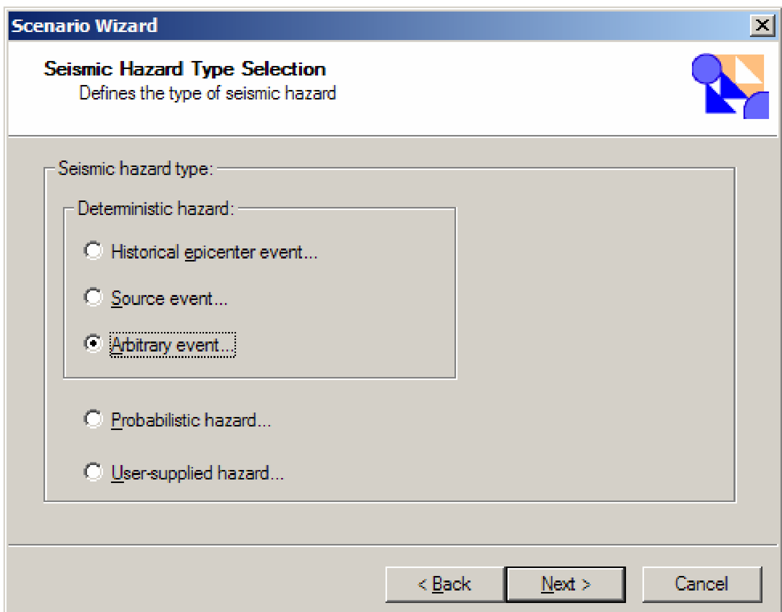


Figure 3.19 Earthquake Hazard Scenario window in HAZUS.

For ground motion, click on **Arbitrary event…** and select to use the "WUS Shallow Crustal Event-Extensional West" attenuation function. Supply the parameters shown in the window in Figure 3.12. At a minimum, you need to supply the latitude and longitude of the event. Without any additional input from you, **HAZUS** will default to a minimum of 5.0 moment magnitude (depending on the attenuation function chosen) with a corresponding surface and subsurface rupture length, a depth of 0 kilometers, a fault rupture orientation of 0 degrees and a strike-slip/normal fault type. Entering data in the appropriate places will change the default values.

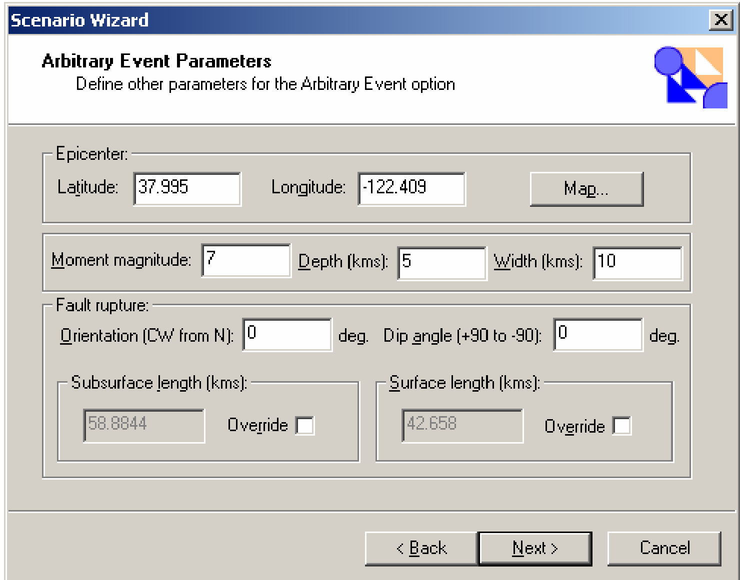


Figure 3.20 Defining an arbitrary earthquake event.

You can also select the latitude and longitude from a map of the region by clicking on the **Map** option. You will be prompted to select a point in the study region by clicking on the screen. Note: The point approximating the epicenter of an arbitrary event must be selected on the study region map without the advantage of additional reference features. Press **Selection Done** when finished; then **Next** > when you are returned to the Arbitrary Event Parameters window.

Name the earthquake event you have just defined with a descriptive title, i.e. "Aribitray M7.0". Press **Next** >, and you will see a summary of the scenario that you just defined (see example Figure 3.21). If the parameters listed are satisfactory, press the **Finish** button to close the scenario definition wizard.

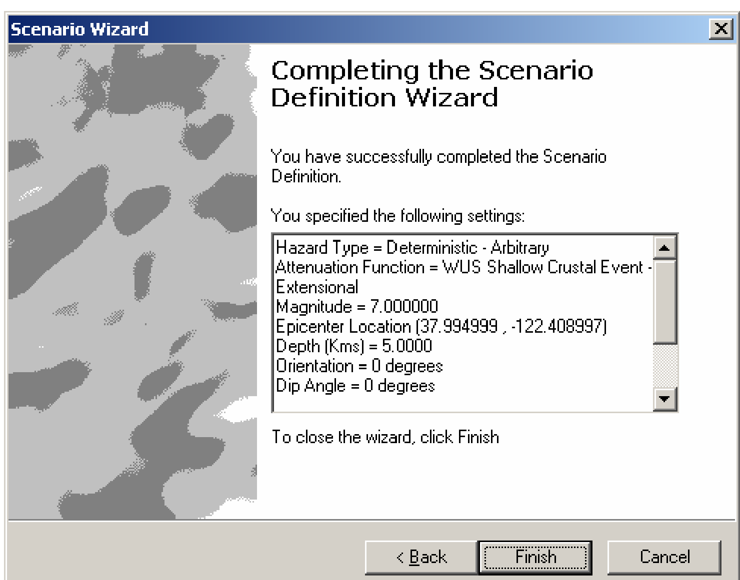


Figure 3.21 Scenario definition wizard and earthquake event parameters.

3.7 Running an Analysis Using Default Data

If you opt to run your analysis with default data and parameters, the only information you will need to supply **HAZUS** is the definition of the study region and the size and location of the scenario earthquake. Defining the study region was discussed in Section 3.1, and definition of the scenario earthquake was outlined in Section 3.6. Once this information has been supplied the analysis can be run.

Figure 3.22 HAZUS Analysis menu.

Select the **Analysis** menu on the main **HAZUS** window to view the options. Damage functions, restoration functions, and parameters may be modified from this menu if the user has local information to improve the analysis. Otherwise, you can run an analysis using only default data and inventory, without modifying any parameters whatsoever.

Choose **Run...** and the window in Figure 3.23 will appear. This window provides a number of analysis options that can be selected by clicking in the associated box. Each option is composed of at least one analysis module; the number is posted near the bottom of the window when the option is selected.

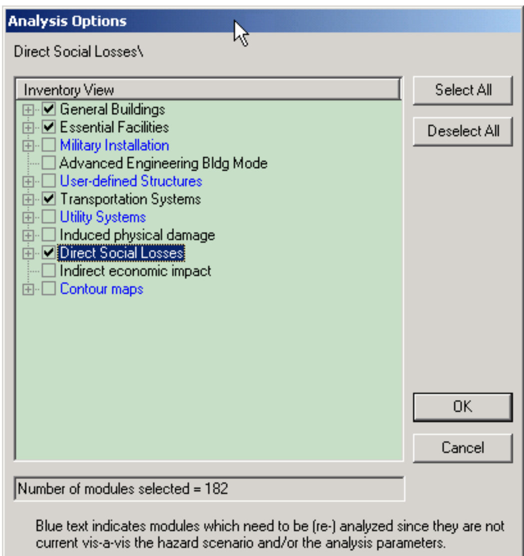


Figure 3.23 Analysis options.

All analysis options can be run at the same time, or each can be run separately. If a study region is large (a few hundred to more than a thousand census tracts), a complete analysis can take several hours. It is suggested that you run the analysis options one at a time while you are developing and modifying scenarios, inventories, and model parameters. This allows you to review intermediate results and check to determine if the results look reasonable, or serve your needs without waiting several hours to run a complete analysis. Once you are satisfied with inventories and model parameters, you may wish to perform additional analyses with all options running simultaneously.

If you wish to ask "what if" questions, individual options can be run repeatedly without performing a complete analysis. Once an option is run, all of the results from that option are saved until it is run again. For example, if a you want to know what would happen if costs of repairs were increased (keeping everything else the same), you would only have to run the **Direct social and economic loss** option again. **HAZUS** will use damage results from the previous analysis to estimate economic losses.

All loss estimation analyses start with the calculation of potential earth science hazards. Results include outputs by census tract, and are viewable in tables and maps. You can view and use contours representing ground motion for display. If specified, you can include liquefaction, landslide and/or surface faulting in the analysis.

When ground motion is mapped by census tract, a constant level of ground motion is displayed for each census tract. Contour maps provide a more detailed mapping of the ground motion and thus take a longer time to generate. Contour maps are for display purposes only and are not used in calculating damage and losses. Users may opt to not generate contour maps if they wish to shorten analysis time.

The Analysis options window from the **Analysis|Run** menu (see Figure 3.24) allows you to specify exactly which damage and losses you want to estimate. For example, you can select to estimate direct physical damage to essential facilities by clicking on and highlighting those items as shown in Figure 3.24. You may specify **Debris** only from the **Induced Physical Damage** window, shown in Figure 3.25 and **Casualties** from the direct social and economic loss window shown in Figure 3.26. Once all of the desired options have been specified, click on the **OK** button to run the analysis.

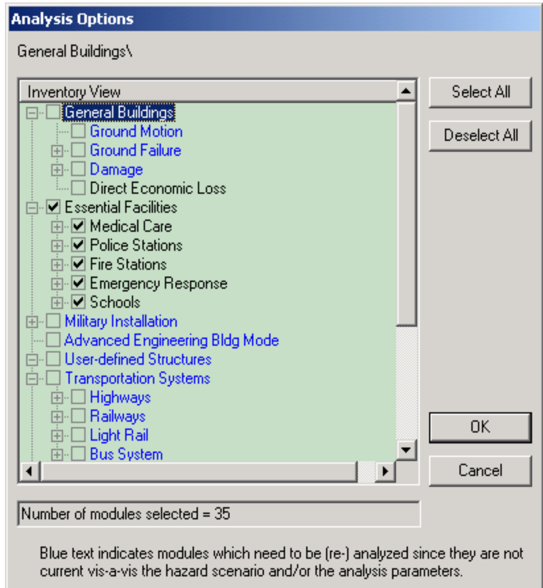


Figure 3.24 Direct physical damage analysis of essential facilities.

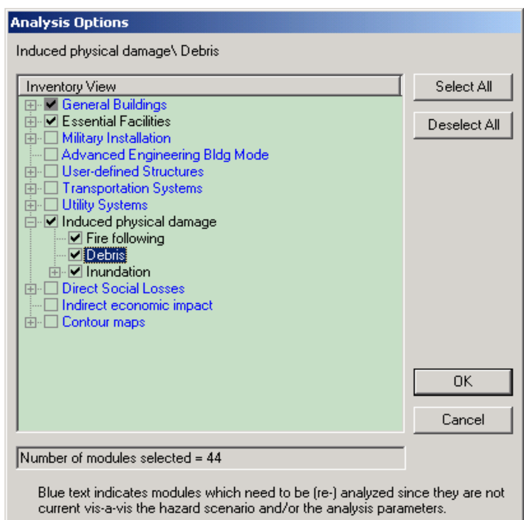


Figure 3.25 Induced physical damage analysis.

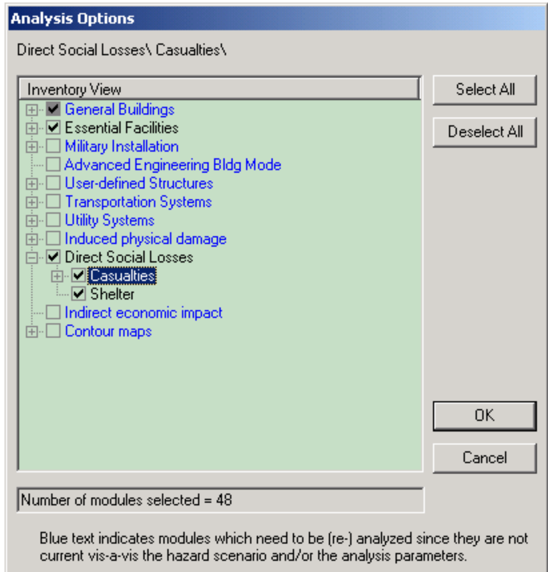


Figure 3.26 Direct social damage analysis.

3.8 Viewing Analysis Results

Each of the modules of **HAZUS** provides the user with a series of outputs. The outputs can be in a tabular or graphical form. Some of the analysis modules yield intermediate results that are used as inputs to other modules. For example, the first calculations estimate the potential earth science hazards to determine ground motion at different locations for a specified earthquake scenario. This information by itself may not be very useful for hazard mitigation and emergency planning. However, these results are used as an input to determine the damage to structures in the Buildings analysis module.

Analysis results are accessed from the **Results** menu as shown in Figure 3.27.

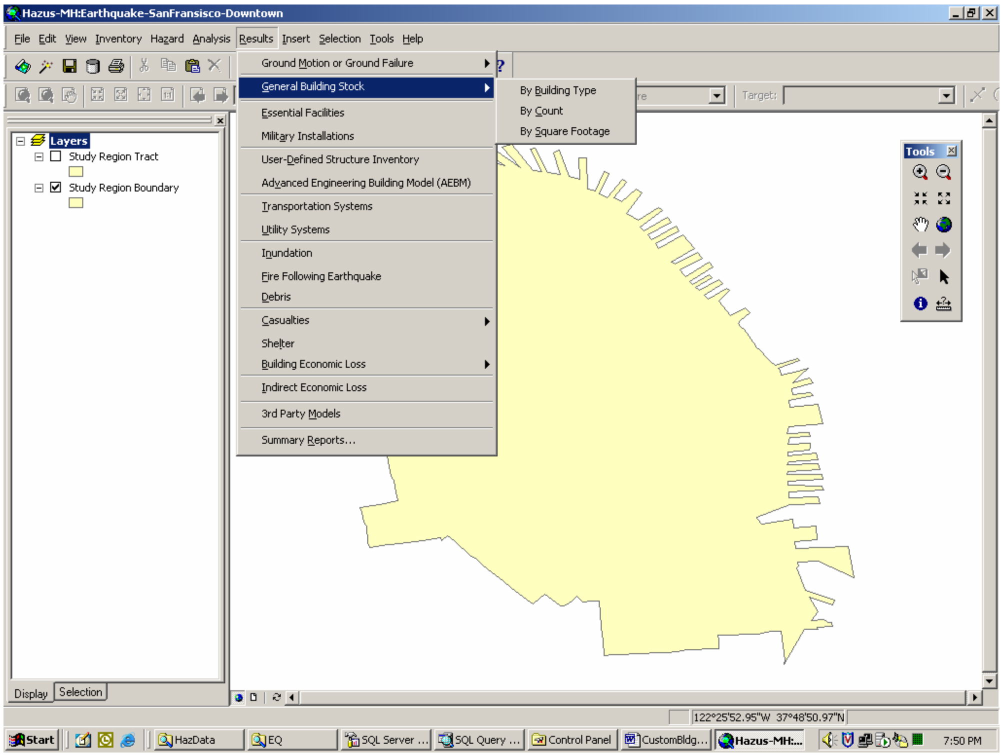


Figure 3.27 HAZUS Results menu.

Three types of output are available:

- Thematic map of results (Figure 3.28 and Figure 3.29)
- Table of results by census tract (Figure 3.30)
- Results summarized by county and for the whole region (Figure 3.31)

Thematic maps use colors and symbols to display results. Results can be thematically mapped by using the **Map** button at the bottom of a table of results (see Figure 3.30). A variety of summary reports are also available using the **Results|Summary Reports** menu from the main menu bar. Displaying results is discussed in more detail in Chapter 10.

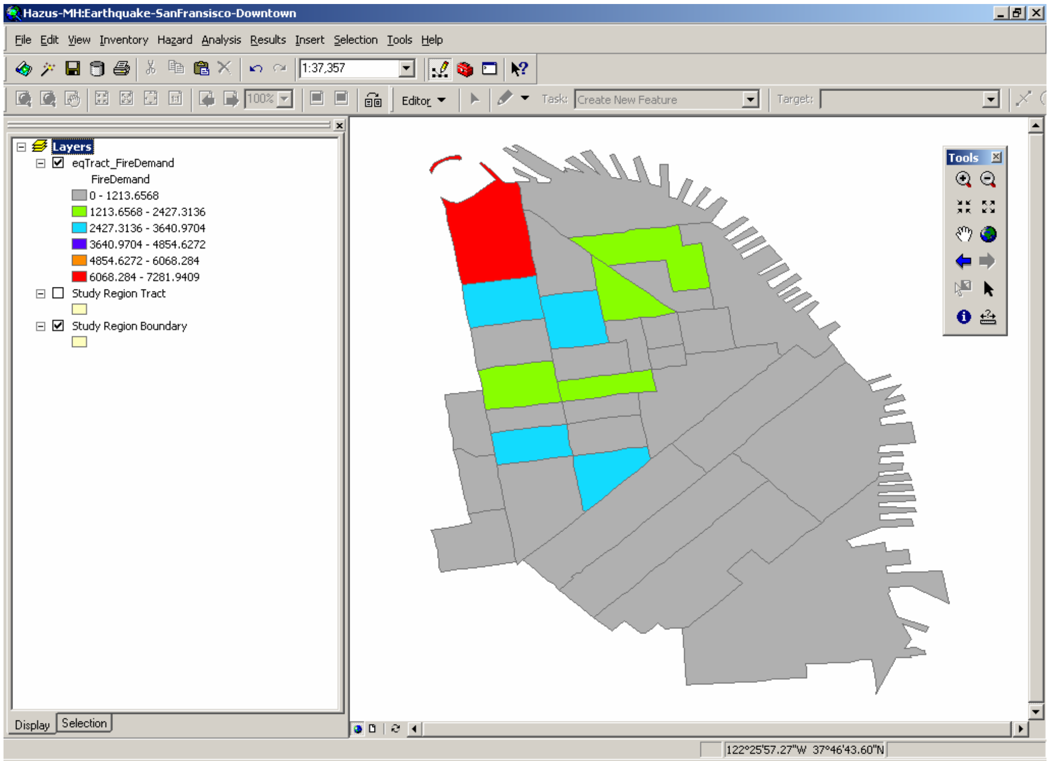


Figure 3.28 Sample thematic map: fire demand for each census tract burned.

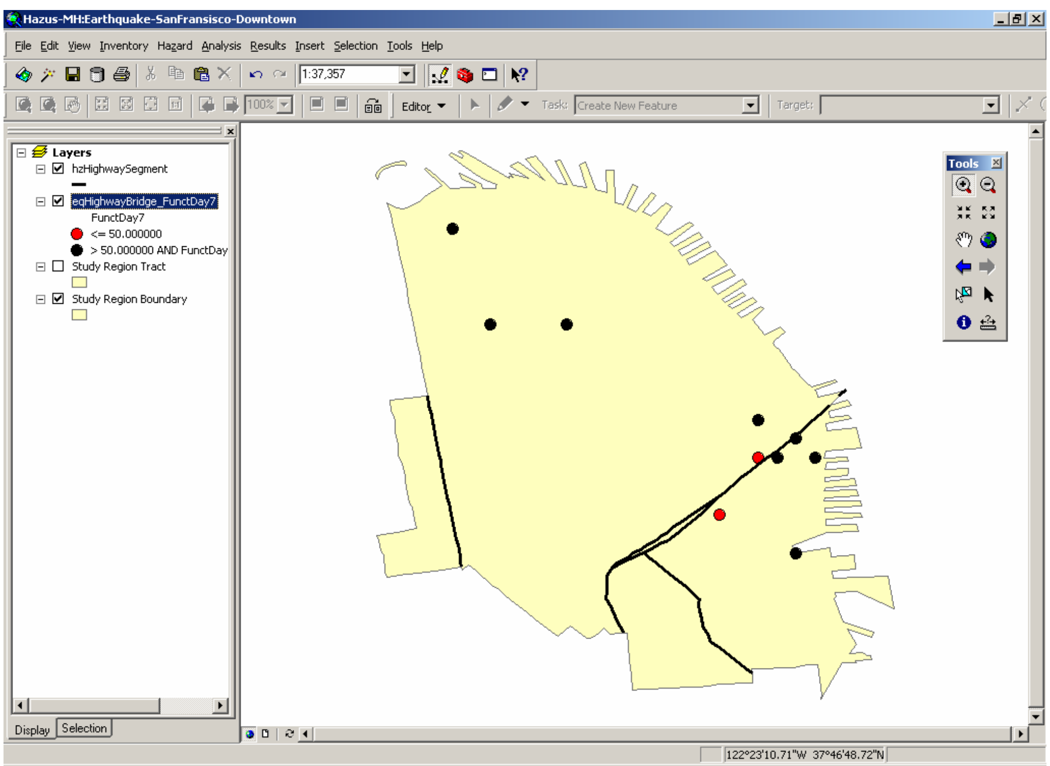
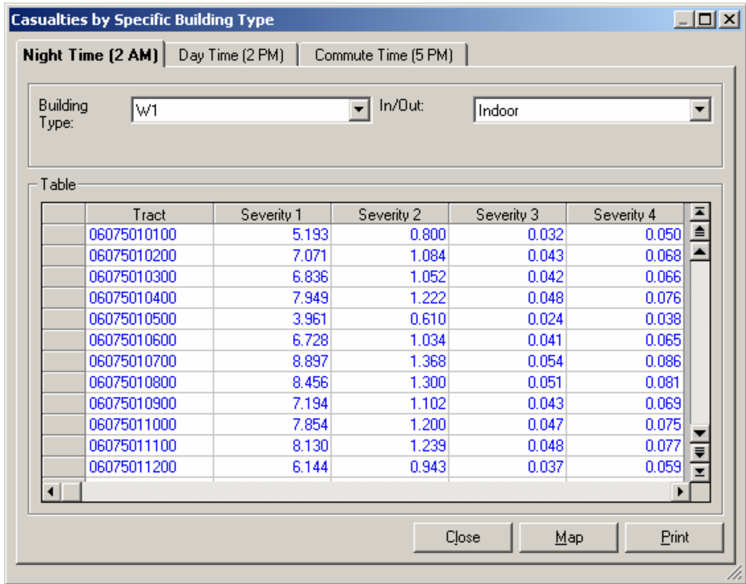


Figure 3.29 Sample thematic map: functionality of highway bridges at 7 days after the earthquake.



Casualties by Specific Building Type

Night Time (2 AM) | Day Time (2 PM) | Commute Time (5 PM)

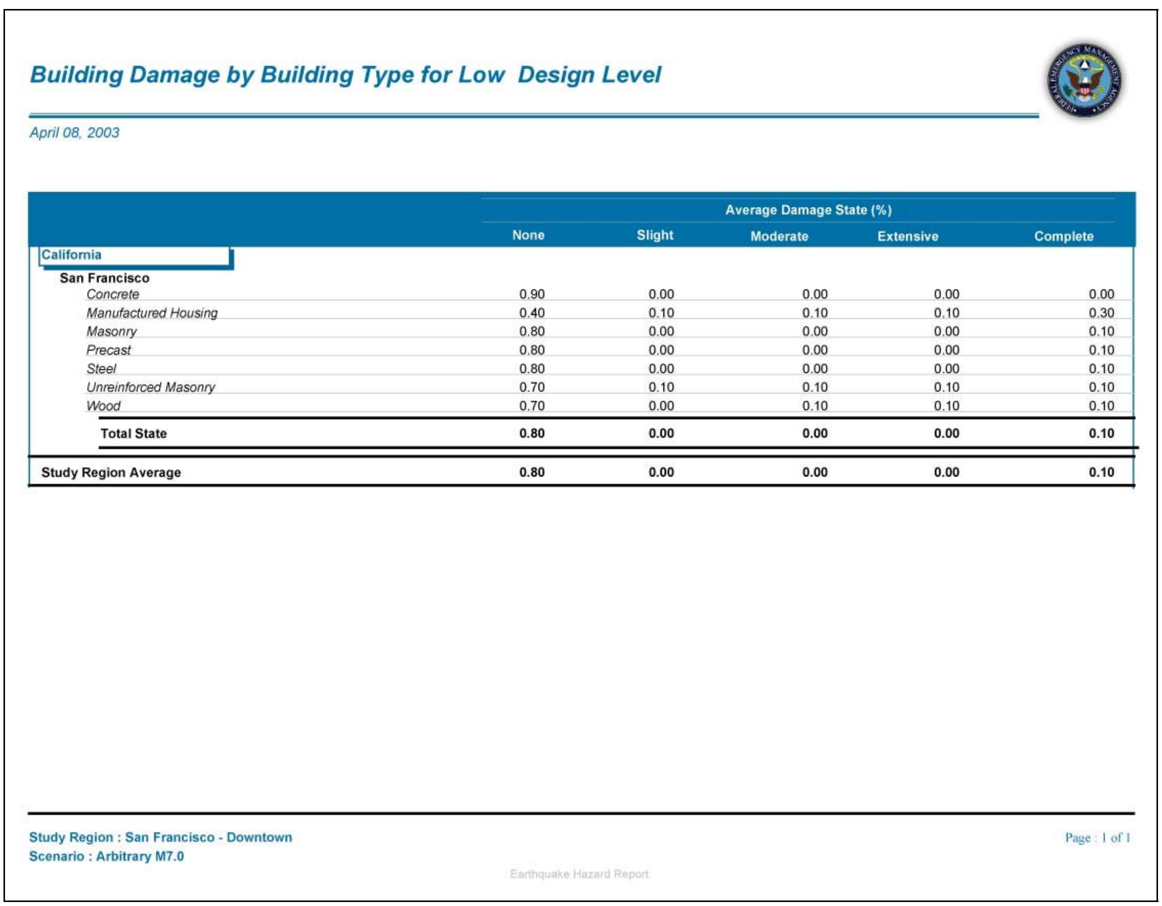
Building Type: W1 In/Out: Indoor

Table

Tract	Severity 1	Severity 2	Severity 3	Severity 4
06075010100	5.193	0.800	0.032	0.050
06075010200	7.071	1.084	0.043	0.068
06075010300	6.836	1.052	0.042	0.066
06075010400	7.949	1.222	0.048	0.076
06075010500	3.961	0.610	0.024	0.038
06075010600	6.728	1.034	0.041	0.065
06075010700	8.897	1.368	0.054	0.086
06075010800	8.456	1.300	0.051	0.081
06075010900	7.194	1.102	0.043	0.069
06075011000	7.854	1.200	0.047	0.075
06075011100	8.130	1.239	0.048	0.077
06075011200	6.144	0.943	0.037	0.059

Close Map Print

Figure 3.30 Sample table of results: residential casualties at 2 AM.



Building Damage by Building Type for Low Design Level

April 08, 2003

	Average Damage State (%) None	Slight	Moderate	Extensive	Complete
California					
San Francisco					
Concrete	0.90	0.00	0.00	0.00	0.00
Manufactured Housing	0.40	0.10	0.10	0.10	0.30
Masonry	0.80	0.00	0.00	0.00	0.10
Precast	0.80	0.00	0.00	0.00	0.10
Steel	0.80	0.00	0.00	0.00	0.10
Unreinforced Masonry	0.70	0.10	0.10	0.10	0.10
Wood	0.70	0.00	0.10	0.10	0.10
Total State	**0.80**	**0.00**	**0.00**	**0.00**	**0.10**
Study Region Average	**0.80**	**0.00**	**0.00**	**0.00**	**0.10**

Study Region : San Francisco - Downtown
Scenario : Arbitrary M7.0

Page : 1 of 1

Earthquake Hazard Report

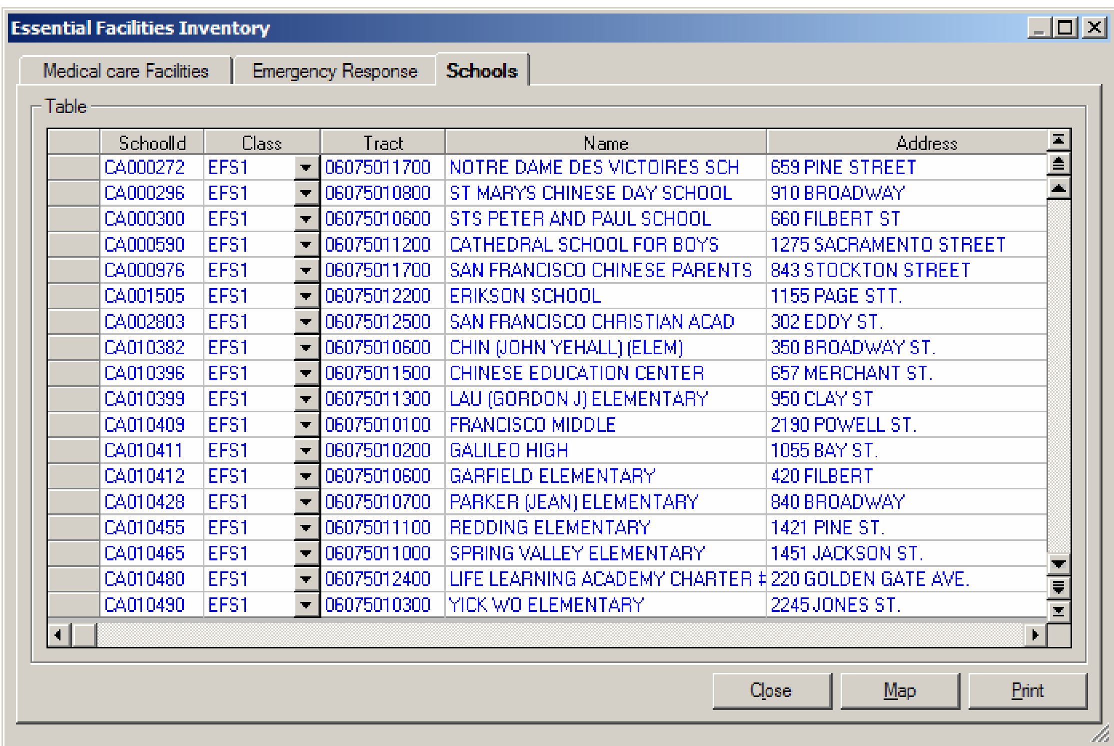
Figure 3.31 Sample summary report: building damage by building type.

3.9 Default Databases and Default Parameters

While most users will develop a local inventory that best reflects the characteristics of their region, such as building types and demographics, **HAZUS** is capable of producing crude estimates of losses based on a minimum of local input. Of course, the quality and uncertainty of the results will be affected by the detail and accuracy of the inventory and the economic and demographic data provided. The crude estimates would most likely be used only as initial estimates to determine where more detailed analyses would be warranted. This section describes the types of data that are supplied as defaults with **HAZUS**.

3.9.1 Default Databases

Default inventory databases provided with **HAZUS** are of two types. The first type is a national listing of <u>individual</u> facilities, such as dams, bridges, or locations where toxic materials are stored (see Figure 3.32). These databases are modified versions of publicly available databases. The modifications that have been made have been to eliminate data elements that are not needed for the earthquake loss estimation methodology.



SchoolId	Class	Tract	Name	Address
CA000272	EFS1	06075011700	NOTRE DAME DES VICTOIRES SCH	659 PINE STREET
CA000296	EFS1	06075010800	ST MARYS CHINESE DAY SCHOOL	910 BROADWAY
CA000300	EFS1	06075010600	STS PETER AND PAUL SCHOOL	660 FILBERT ST
CA000590	EFS1	06075011200	CATHEDRAL SCHOOL FOR BOYS	1275 SACRAMENTO STREET
CA000976	EFS1	06075011700	SAN FRANCISCO CHINESE PARENTS	843 STOCKTON STREET
CA001505	EFS1	06075012200	ERIKSON SCHOOL	1155 PAGE STT.
CA002803	EFS1	06075012500	SAN FRANCISCO CHRISTIAN ACAD	302 EDDY ST.
CA010382	EFS1	06075010600	CHIN (JOHN YEHALL) (ELEM)	350 BROADWAY ST.
CA010396	EFS1	06075011500	CHINESE EDUCATION CENTER	657 MERCHANT ST.
CA010399	EFS1	06075011300	LAU (GORDON J) ELEMENTARY	950 CLAY ST
CA010409	EFS1	06075010100	FRANCISCO MIDDLE	2190 POWELL ST.
CA010411	EFS1	06075010200	GALILEO HIGH	1055 BAY ST.
CA010412	EFS1	06075010600	GARFIELD ELEMENTARY	420 FILBERT
CA010428	EFS1	06075010700	PARKER (JEAN) ELEMENTARY	840 BROADWAY
CA010455	EFS1	06075011100	REDDING ELEMENTARY	1421 PINE ST.
CA010465	EFS1	06075011000	SPRING VALLEY ELEMENTARY	1451 JACKSON ST.
CA010480	EFS1	06075012400	LIFE LEARNING ACADEMY CHARTER ł	220 GOLDEN GATE AVE.
CA010490	EFS1	06075010300	YICK WO ELEMENTARY	2245 JONES ST.

Figure 3.32 Default inventories: Modified public databases (schools)

The second type of default database consists of data aggregated on a county or census tract scale. Examples are building stock square footage for each census tract and census demographic data (see Figure 3.33). These default databases are also derived from publicly available data, eliminating fields of data that are not needed for the methodology.

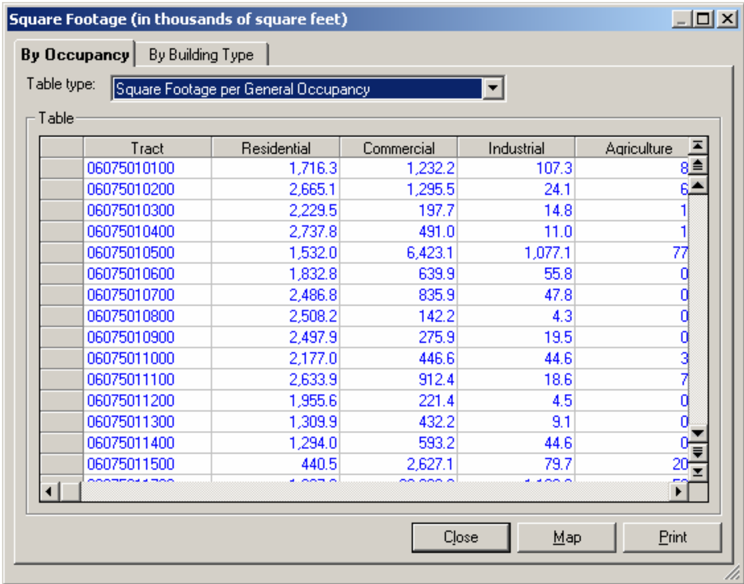


Figure 3.33 Default inventories: Aggregated building data.

The databases are stored on the **HAZUS** State Data DVDs. When you aggregate a region, **HAZUS** extracts only those portions of the databases that are relevant to your study region. You can then access these region-specific default databases and update them with improved information that you have obtained. Displaying and modifying inventories is discussed in Chapter 7.

Appendix D enumerates all the default databases included with the earthquake module of **HAZUS**. Following is a list of default inventory information currently supplied with **HAZUS**:

- **Demographic Data**
  - Population Distribution
  - Age, Ethnic, and Income Distribution
- **General Building Stock**
  - Square Footage of Occupancy Classes for Each Census Tract
- **Essential Facilities**
  - Medical Care Facilities
  - Emergency Response Facilities (fire stations, police stations, EOCs)
  - Schools
- **High Potential Loss Facilities**
  - Dams
  - Nuclear Power Plants
  - Military Installations
- **Facilities Containing Hazardous Materials**
- **Transportation Lifelines**
  - Highway Segments, Bridges and Tunnels
  - Railroad Tracks, Bridges, Tunnels and Facilities
  - Light Rail Tracks, Bridges, Tunnels and Facilities
  - Bus Facilities
  - Port Facilities
  - Ferry Facilities
  - Airports Facilities and Runways
- **Utility Lifelines**
  - Potable Water Facilities, Pipelines and Distribution Lines
  - Waste Water Facilities, Pipelines and Distribution Lines
  - Oil Facilities and Pipelines
  - Natural Gas Facilities, Pipelines and Distribution Lines
  - Electric Power Facilities and Distribution Lines
  - Communication Facilities and Distribution Lines

3.9.2 Default Parameters

In addition to default databases, the user is supplied with default parameters documented throughout the Technical Manual. Access the **HAZUS** parameters from the **Analysis|Parameters** menu, shown in Figure 3.34. In many cases these parameters are defined on a national basis without adjustments for regional variations. In other cases such as with repair costs, regional variations are included.

Figure 3.34 Analysis Parameters menu.

Examples of default parameters are costs per square foot to repair a structure, percent of residences that are owner occupied, and casualty rates for specific building types experiencing different damage states. Default relationships between occupancy classes and building types are provided to infer building inventory characteristics. Fragility curves (used for estimating damage) with default means and variances are supplied for each model building type. The user can modify all of these parameters if better information is available (inferred in Figure 3.35). Modifying default parameters is discussed in Chapters 4 through 8.

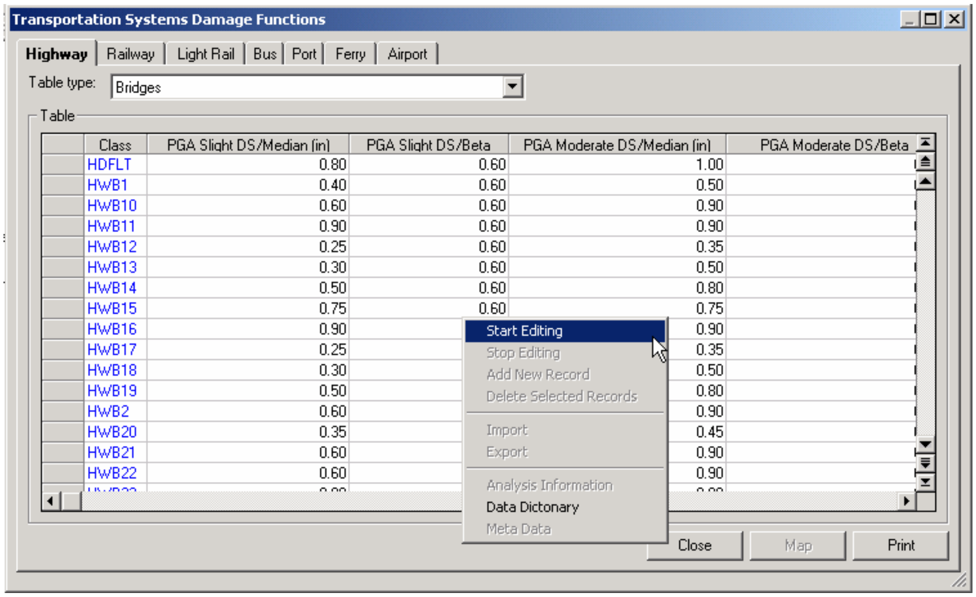


Figure 3.35. Damage function parameter values can be edited.

Chapter 4. Data Needed for More Complete Loss Estimation Study

Figure 4.1 shows the steps that are typically performed in assessing and mitigating the impacts of a natural hazard such as an earthquake, hurricane or flood. In order to estimate regional losses resulting from a natural disaster, you need to have an understanding of both the size of the potential event (hazard identification) and the characteristics of the population and the environment that will be impacted (inventory collection). For example, a flood that occurs near a densely populated region will cause different types of losses than one that occurs in a mostly agricultural region. Similarly, the economic impacts of an earthquake in a highly industrialized region will be different from those in a region that predominantly supports a service economy. Thus, to reliably model the losses in your region, you will need to collect a wide variety of data so as to be able to characterize the buildings and lifelines, the population, and the structure of the local economy.

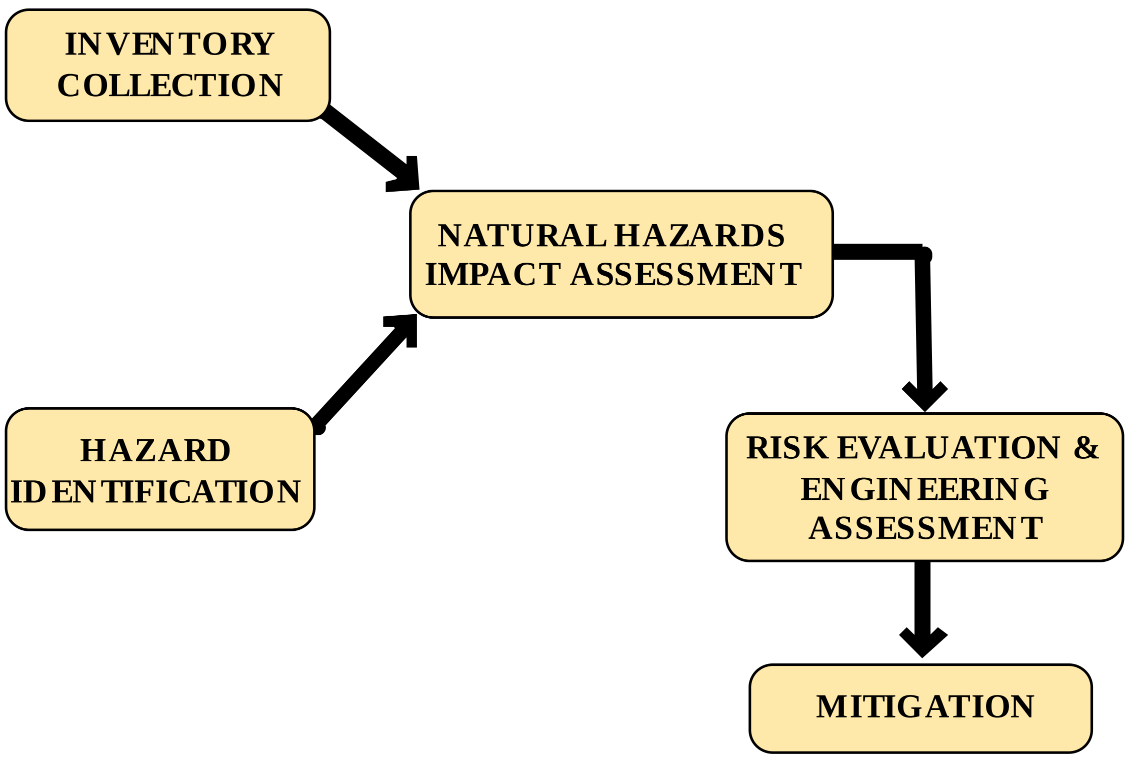


Figure 4.1 Steps in assessing and mitigating losses dues to natural hazards.

4.1 Developing a Regional Inventory

In developing a regional inventory, it is almost impossible from a cost point of view to identify and inventory each man-made structure individually. Some important structures such as hospitals, schools, emergency operation centers, fire stations, important bridges, and electrical power substations may be identified individually, but the majority of buildings in a region are grouped together collectively and identified by their total value or square footage.

To permit modeling of spatial variation in types and occupancies of buildings, a region is built up from sub-regions, and the inventory is collected for each sub-region. In the earthquake loss estimation methodology, **census tracts** are used as the basic sub-region unit, and all regions are built up by aggregating census tracts. Thus for each census tract, your inventory might consist of the number of square feet of wood frame buildings, the number of square feet of unreinforced masonry buildings and so on for each building type.

Figure 4.2 shows the inventory of single-family residential construction in a region, expressed as building count by occupancy type. Note that the number of single-family residential buildings is stored and displayed for each census tract in the region. Likewise, the totol value of residential units in each census tract can be estimated, as in Figure 4.3, and used as a general guide to residential risk exposure (in dollars) in each area.

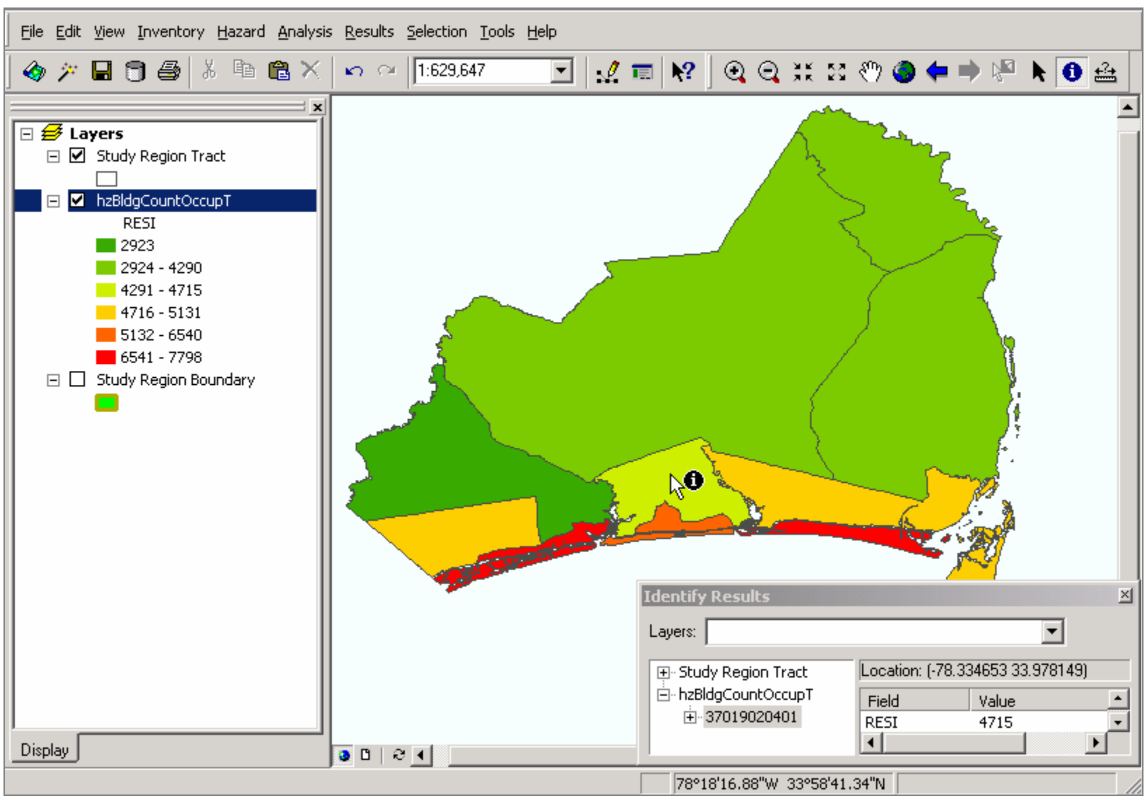


Figure 4.2 Residential occupancy by census tract.

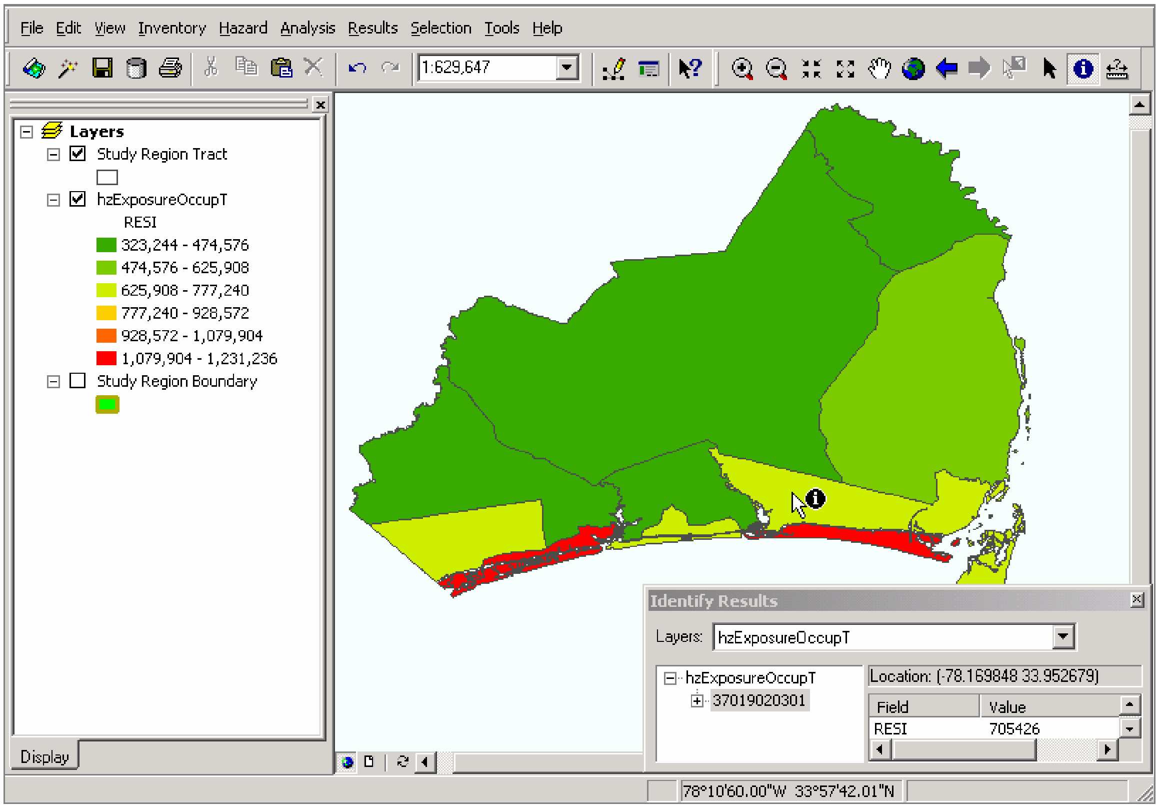


Figure 4.3 Value of single-family residential homes (RES1) by census tract.

In the methodology, the residential, commercial and industrial buildings that are not identified individually (user-defined structures, i.e. historic buildings) are called **general building stock**. General building stock is inventoried by calculating, for each census tract, the total square footage of groups of buildings with specific characteristics (i.e., calculating the total square footage of low-rise unreinforced masonry structures).

Collecting even this “simplified” inventory can be problematic. There are rarely reliable and complete databases that provide the necessary information such as building size, building occupancy, building height and structural system that could be used to obtain total values for each census tract. Therefore, inferences are made about large groups of buildings based on land use patterns, census information, business patterns, assessors’ files, insurance files, etc. Inferences can take the form, “if this is a residential area, 50% of the buildings are single family wood structures and 50% are multi-family wood structures”.

While there are inaccuracies in the inventory of general building stock due to inferences that are made, the error tends to be random and can be accounted for in the probabilistic aspects of the methodology. Similar types of inferences are made with respect to lifeline systems (e.g., the number of miles of water supply pipe in a census tract may be inferred from the number of miles of streets).

In contrast to the inventory of general building stock which is maintained in terms of total value per census tract, facilities that have some special significance such as essential facilities or components of lifeline systems (ex. Communication centers) can be maintained in the database by individual location. Correspondingly, losses for essential facilities and some lifeline components are computed for individual facilities, while losses for general building stock are calculated by census tract.

While some inferences can be used for site-specific facilities when data are unavailable, often you will have better access to databases about these facilities than you will for general building stock. Sometimes there will be few enough of these facilities that you can actually go to the site and collect the required inventory information. Sources of inventory information and how to go about collecting it are discussed in Chapter 5.

4.2 Standardizing and Classifying Data

There are two issues that must be considered in the development of an inventory: classification of data, and collection and handling of data. Classification systems are essential to ensuring a uniform interpretation of data and results. As discussed earlier, it is almost impossible, from a cost point of view, to identify and individually inventory each building or component of each lifeline. Thus losses in a regional study are estimated based on general characteristics of buildings or lifeline components, and classification systems are a tool to group together structures or lifeline components that would be expected to behave similarly in a seismic event. For each of the types of data that must be collected to perform a loss study, a classification system has been defined in this methodology.

4.2.1 Building Classification – Model Building Types

The building classification system used in this methodology has been developed to provide an ability to differentiate between buildings with substantially different damage and loss characteristics. In general, buildings behave differently due to the types of structural systems they have (i.e. wood versus steel), the codes to which they were designed, their heights, their shapes or footprints, and local construction practices.

As a consequence of the variations in design, shape, height etc., no two buildings will behave exactly the same when subjected to an earthquake. Therefore, **model building types** are defined to represent the average characteristics of buildings in a class. Within any given building class there will be a great deal of variation. The damage and loss prediction models in this methodology are developed for model building types and the estimated performance is based upon the “average characteristics” of the total population of buildings within each class.

Table 4.1 provides a summary of the 36 model building types that have been defined in the methodology. Each model building type is defined by a short description of the related structural system. These short descriptions can be found in Appendix B. It can be seen in the table in Appendix B that there are 16 general model building types (shown in bold) with some building types being subdivided by height. In addition, the seismic design level, which reflects the relationship between design quality and extent of damage, can be used to further classify each model building type. Four design levels are defined in the methodology: High-Code, Moderate-Code, Low-Code and Pre-Code. For a detailed discussion of how the classification system was developed and the characteristics that were used to differentiate classes, see Chapters 3 and 5 of the Technical Manual.

Table 4.1 Structural building classifications (Model Building Types)

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1 2	W1 W2	Wood, Light Frame (≤ 5,000 sq. ft.) Wood, Commercial and Industrial (> 5,000 sq. ft.)		1 - 2 All	1 2	14 24
3 4 5	S1L S1M S1H	Steel Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
6 7 8	S2L S2M S2H	Steel Braced Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
9	S3	Steel Light Frame		All	1	15
10 11 12	S4L S4M S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
13 14 15	S5L S5M S5H	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
16 17 18	C1L C1M C1H	Concrete Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
19 20 21	C2L C2M C2H	Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
22 23 24	C3L C3M C3H	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
25	PC1	Precast Concrete Tilt-Up Walls		All	1	15
26 27 28	PC2L PC2M PC2H	Precast Concrete Frames with Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
29 30	RM1L RM2M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise Mid-Rise	1-3 4+	2 5	20 50
31 32 33	RM2L RM2M RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
34 35	URML URMM	Unreinforced Masonry Bearing Walls	Low-Rise Mid-Rise	1 - 2 3+	1 3	15 35
36	MH	Mobile Homes		All	1	10

4.2.2 Building Classification – Building Occupancy

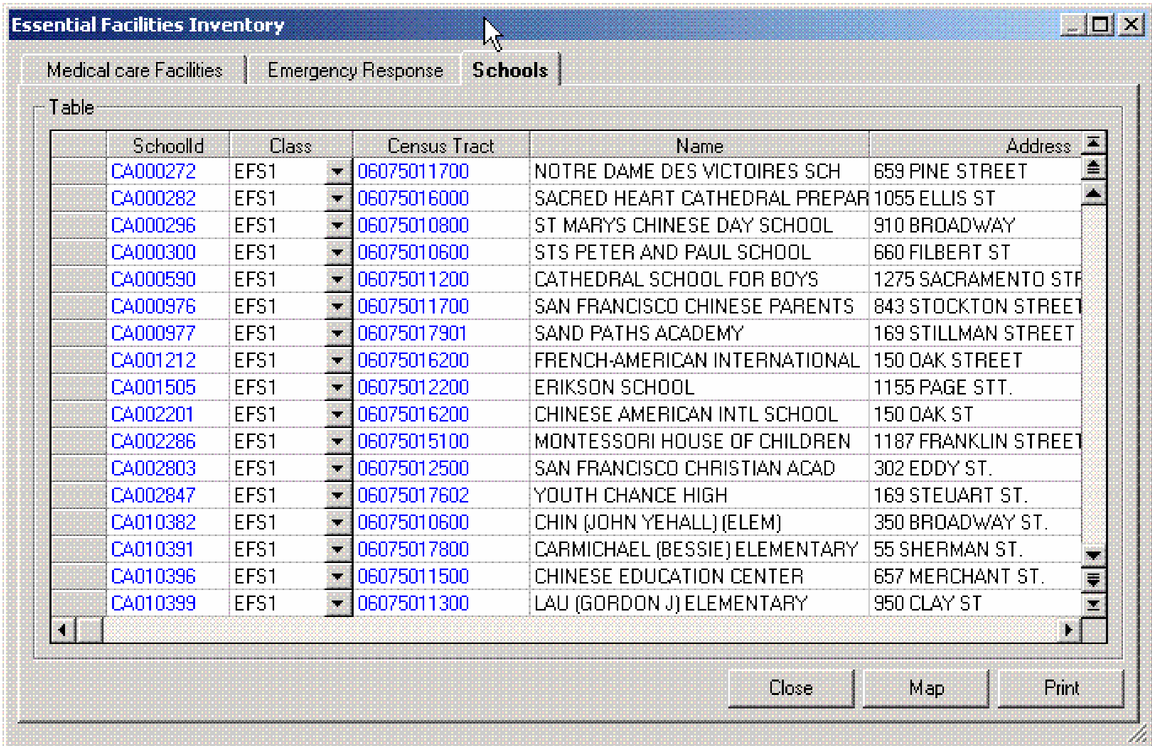
General building stock is also classified based on occupancy. The occupancy classification is broken into **general occupancy** and **specific occupancy** classes. For the methodology, the general occupancy classification system consists of six groups: residential, commercial, industrial, religion/non profit, government, and education. Specific occupancy consists of 33 classes. Occupancy classes are used to account for the fact that contributions to losses are from damage to both the structural system and non-structural elements. The types and costs of non-structural elements are often governed by the occupancy of the building, e.g. in a warehouse there may be few expensive wall coverings; whereas, a bank may have expensive lighting and wall finishes.

If the structural systems of these two buildings experience the same amount of damage, the costs to repair the bank will be greater than the warehouse due to the more expensive finishes. Other issues related to occupancy may also be important, such as rental costs, number of employees, type of building contents and importance of function. Finally, a great deal of inventory information, such as county business patterns or census data, is only available by occupancy.

Classification systems developed for soils, model building types, building occupancies, essential facilities, high potential loss facilities, and lifelines are listed in Appendix A. Descriptions of the characteristics of lifeline components are found in Appendix C.

4.3 Inventory Databases

Once data have been collected, they can be accessed more easily and updated in the future if they are maintained in an orderly manner. Database formats have been developed for all of the data that you will collect to perform the loss study. Figure 4.4 is an example of a database of school facilities as you would see it when using **HAZUS**.



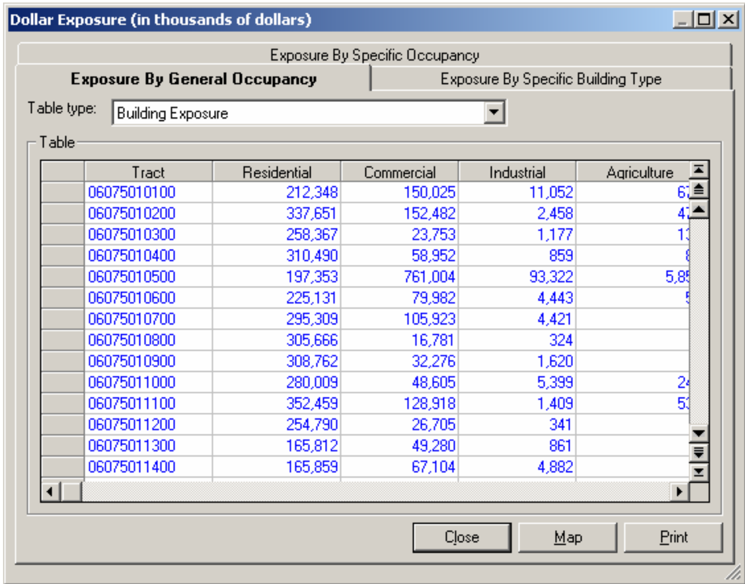
SchoolId	Class	Census Tract	Name	Address
CA000272	EFS1	06075011700	NOTRE DAME DES VICTOIRES SCH	659 PINE STREET
CA000282	EFS1	06075016000	SACRED HEART CATHEDRAL PREPAR	1055 ELLIS ST
CA000296	EFS1	06075010800	ST MARYS CHINESE DAY SCHOOL	910 BROADWAY
CA000300	EFS1	06075010600	STS PETER AND PAUL SCHOOL	660 FILBERT ST
CA000590	EFS1	06075011200	CATHEDRAL SCHOOL FOR BOYS	1275 SACRAMENTO STR
CA000976	EFS1	06075011700	SAN FRANCISCO CHINESE PARENTS	843 STOCKTON STREET
CA000977	EFS1	06075017901	SAND PATHS ACADEMY	169 STILLMAN STREET
CA001212	EFS1	06075016200	FRENCH-AMERICAN INTERNATIONAL	150 OAK STREET
CA001505	EFS1	06075012200	ERIKSON SCHOOL	1155 PAGE STT.
CA002201	EFS1	06075016200	CHINESE AMERICAN INTL SCHOOL	150 OAK ST
CA002286	EFS1	06075015100	MONTESSORI HOUSE OF CHILDREN	1187 FRANKLIN STREET
CA002803	EFS1	06075012500	SAN FRANCISCO CHRISTIAN ACAD	302 EDDY ST.
CA002847	EFS1	06075017602	YOUTH CHANCE HIGH	169 STEUART ST.
CA010382	EFS1	06075010600	CHIN (JOHN YEHALL) (ELEM)	350 BROADWAY ST.
CA010391	EFS1	06075017800	CARMICHAEL (BESSIE) ELEMENTARY	55 SHERMAN ST.
CA010396	EFS1	06075011500	CHINESE EDUCATION CENTER	657 MERCHANT ST.
CA010399	EFS1	06075011300	LAU (GORDON J) ELEMENTARY	950 CLAY ST

Figure 4.4 Database of school facilities.

The database contains fields that allow you to store a variety of attributes about each facility. For example, in addition to the name, address, and city of the school facility (as shown in Figure 4.4), there are data fields to enter zip code, contact name and phone number at the facility, class of facility (e.g. elementary, secondary), number of students, and the structural type. There is also a “comments” field that allows you to include any information that does not fit into other fields.

Some of these fields are not shown in the above figure, but can be accessed if you scroll to the right. Some of the essential facilities may be missing information such as address. A missing address does not prevent a facility from being included in the database or in the analysis. In order to be included, only the latitude, longitude and county need be specified while other attributes can be inferred (with corresponding uncertainty).

Figure 4.5 shows an inventory database for general building stock. For general building stock, data are stored by census tract and for each census tract you will find the total monetary value for each of the seven general occupancy types: residential, commercial, industrial, agricultural, religious/non-profit, governmental and educational. For example, in census tract 37019020501, the value of residential construction is \$23.2 million and for commercial construction is \$79.5 million. The inventory can also be viewed in terms of each specific occupancy types (RES1, RES2, RES3A, etc.) by clicking on **Exposure By Specific Occupancy** tab to the left of the general classifications at the top of Figure 4.5. At the lower right of the window, the **Map** button allows the user to graphically display the information by census tract.



Tract	Residential	Commercial	Industrial	Agriculture
06075010100	212,348	150,025	11,052	6
06075010200	337,651	152,482	2,458	4
06075010300	258,367	23,753	1,177	1
06075010400	310,490	58,952	859	
06075010500	197,353	761,004	93,322	5,8
06075010600	225,131	79,982	4,443	
06075010700	295,309	105,923	4,421	
06075010800	305,666	16,781	324	
06075010900	308,762	32,276	1,620	
06075011000	280,009	48,605	5,399	2
06075011100	352,459	128,918	1,409	5
06075011200	254,790	26,705	341	
06075011300	165,812	49,280	861	
06075011400	165,859	67,104	4,882	

Figure 4.5 Value of general building stock inventory.

You will find that data entry is in a familiar spreadsheet format to allow for easy entry and modification. Moving around in the database involves using the arrow keys at the bottom and to the right of the window. Discussion of how to display, print, modify and map your inventories is found in Chapter 7. All data are stored in a SQL Server database[3]. The structures of all the parameter and inventory databases that are maintained by **HAZUS** are found in Appendix E: Data Dictionary. A discussion of default databases is found in Section 3.9.

4.4 Inventory Requirements

Each module in the earthquake loss estimation methodology requires a specific set of input data. The required data can take two forms. The first is inventory data such as the square footage of buildings of a specified type, the length of roadways or the population in the study region. These are used to estimate the amount of exposure or potential damage in the region. The second data type includes characteristics of the local economy that are important in estimating losses (e.g., rental rates, construction costs or regional unemployment rates). This section summarizes the inventory information that is needed to perform a loss study.

Table 4.2 lists the inventory required for each type of output that is provided in the methodology. You will find that there are varying degrees of difficulty in developing this inventory. For example, in your region excellent records may be available concerning the police and fire stations and schools. On the other hand you may find that it is difficult to obtain detailed information about some of the lifeline facilities.

[3] To be accurate, only the attributes tables are stored in SQL Server. Mappable tables have the attributes stored in SQL Server and the map objects stored in an ArcMap geodatabase (*.mdb).

An issue that you will likely run into is that data you collect will have to be adjusted so that the inventory is classified according to the systems defined in the methodology. For example, a school may have two building wing additions that were constructed over the forty-year lifetime of the structure. Each era of construction used improved materials, but the best materials were used to construct the smallest addition. The individual responsible for assigning the building type of the school according to the **HAZUS** methodology will need to define and document the criteria applied to classify the structure. Easiest approach is to break the facility into different entries, ie records.

In some cases, you may find that you require a consultant to assist with the classification of data. Default values are provided for most of the input information (see Section 3.9). In Table 4.2, a star is placed next to those input requirements that do not have default values.

Table 4.2 Minimum inventory for the Earthquake Loss Estimation Methodology

Desired Output	Required Input
POTENTIAL EARTH SCIENCE HAZARDS (PESH)	
Intensities of ground shaking for scenario earthquake	Definition of scenario earthquake and attenuation functions, soil map
Permanent ground displacements	Liquefaction and landslide susceptibility maps
Liquefaction probability	Liquefaction susceptibility map
Landsliding probability	Landslide susceptibility map
GENERAL BUILDING STOCK	
Damage to general building stock by occupancy or building type	Total square footage of each occupancy by census tract, occupancy to building type relationships
ESSENTIAL FACILITIES	
Damage and functionality of essential facilities	Location and building type of each facility
Loss of beds and estimated recovery time for hospitals	Number of beds at each facility
HIGH POTENTIAL LOSS FACILITIES	
Map of high potential loss facilities	Locations and types of facilities
Damage and loss for military installations	Location, building type, and value of military installations
TRANSPORTATION LIFELINES	
Damage to transportation components	Locations and classes of components
Restoration times of transportation components	Estimates of repair times for each level of damage
UTILITY LIFELINES	
Damage to utility components	Locations and classes of components
Restoration times of utility components	Estimates of repair times for each level of damage
INDUCED PHYSICAL DAMAGE	
Inundation exposure	Inundation map
Number of ignitions and percentage of burned area by census tract	General building stock inventory, average speed of fire engines, and speed and direction of wind

Map of facilities containing hazardous materials	Inventory of facilities containing hazardous materials
Type and weight of debris	General building stock inventory and estimates of type and unit weight of debris
DIRECT SOCIAL LOSSES	
Number of displaced households	Number of households per census tract
Number of people requiring temporary shelter	Population including ethnicity, age, income
Casualties in four categories of severity based on event at three different times of day	Population distribution at three times of day
ECONOMIC LOSSES	
Structural and nonstructural cost of repair or replacement	Cost per square foot to repair damage by structural type and occupancy for each level of damage
Loss of contents	Contents value as percentage of replacement value by occupancy
Business inventory damage or loss	Annual gross sales in $ per square foot
Relocation costs	Rental costs per month per square foot by occupancy
Business income loss	Income in $ per square foot per month by occupancy
Employee wage Loss	Wages in $ per square foot per month by occupancy
Loss of rental income	Rental costs per month per square foot by occupancy
Cost of damage to transportation components	Costs of repair/replacement of components
Cost of damage to utility components	Costs of repair/replacement of components
INDIRECT ECONOMIC LOSSES	
Long-term economic effects on the region	Unemployment rates, input/output model parameters

4.5 Relationship between Building Types and Occupancy Classes

As discussed earlier, contributions to the loss estimates come from damage to both the structural system and the non-structural elements. In order to estimate losses, the structural system must be known, or inferred for all of the buildings in the inventory. Since much of the inventory information that is available is based on occupancy classes, inferences must be made to convert occupancy class inventory to model building types. These inferences affecting inventory can introduce uncertainty in the loss estimates.

The relationship between structural type and occupancy class will vary on a regional basis. For example, in California, the occupancy RES1 (single family dwelling) can be 95% W1 (wood, light frame) and 5% URML (unreinforced masonry bearing wall, low rise). In a city on the east coast, the relationship can be 40% W1, 50% URML and 10% RM1L (reinforced masonry bearing wall with wood or metal deck diaphragm, low rise).

In most cases, structures in a study region or census tract have been built at different times. As a result, some structures might have been built before 1950, some between 1950 and 1970 and others after 1970. An exception can be a large development that occurred over a short period in which most structures would have about the same age.

Since construction practices change over time, so does the mix of structural types. For example, Table 4.3 shows a typical mix of low-rise model building types for west coast construction for occupancy class COM1 (retail trade). Looking at the building type S5L (low rise steel frame with unreinforced masonry infill walls) it can be seen that before 1950, 20% of stores were built using this structural system, whereas after 1970 none were.

Table 4.3 Distribution of floor area for occupancy COM1,

Age	Model Building Type													
	2	**3**	**6**	**9**	**10**	**13**	**16**	**19**	**22**	**25**	**26**	**29**	**31**	**34**
	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
Pre-1950	22%	2%		6%	3%	20%		17%	1%			6%		23%
1950 to 1970	34%	3%	1%	3%	2%	4%		13%	5%	10%	1%	18%	2%	4%
Post-1970	26%	9%	1%	2%	1%		6%	10%	1%	15%	5%	21%	3%	

While the relationship shown in Table 4.3 can be developed from data collected locally, **HAZUS** provides default mappings of specific occupancy classes to model building types. Three general mapping schemes have been defined and assigned depending upon whether a state is in the Western U. S., the Mid-West or the Eastern U. S. Table 3C.1 of the *Technical Manual* provides the regional classification for each state. Default mappings will be the same for regions that are created anywhere within a particular state. It will be up to you to modify these defaults to reflect characteristics that are specific to your local region.

In addition to geographical location, the distributions can also depend on when the buildings were constructed and whether they are low, medium or high-rise structures. Age is important because it affects the types of structures that exist in a region. For example, if most of the buildings in a region were built after 1970, there will be very few unreinforced masonry structures. An example of how age and height information affects the mix of building types is shown as follows:

Suppose you determined the following information:

All of the buildings in a census tract are low-rise
50% of the buildings were built before 1950
30% of the buildings were built between 1950 and 1970
20% of the buildings were built after 1970.

A new occupancy mapping can be calculated by combining the different mapping schemes presented in Table 4.3. The new occupancy mapping for COM1 would be determined by multiplying the first row of Table 4.3 by 0.5, the second row by 0.3, the third row by 0.2 and then summing. To calculate the modified occupancy mapping for the building type W2, the calculation would be:

$$0.5 \text{ x } 22\% + 0.3 \text{ x } 34\% + 0.2 \text{ x } 26\% = 26\%$$

The resulting occupancy mapping is shown in Table 4.4. Similar calculations would occur if you were also to include a mix of building heights.

Table 4.4 Modified occupancy mapping for COM1 to include age mix

Specific Occupancy Class	Model Building Type													
	2	3	6	9	10	13	16	19	22	25	26	29	31	34
	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
COM1	26%	4%	1%	4%	2%	11%	1%	15%	2%	6%	1%	13%	1%	13%

Modifying occupancy to model building type relationships in **HAZUS** is discussed in Chapter 7. Developing custom mapping schemes using local data and experts is discussed in Chapter 5. Developing mapping schemes using tax assessor or property records is discussed in Chapter 8.

Chapter 5. Collecting Inventory Data

A limiting factor in performing a loss estimation study is the cost and quality of the inventory. Collection of inventory is without question the most costly part of performing the study. Crude estimates of damage do not require extensive inventory data and can be performed on a modest budget. As the damage estimates become more precise, the need for inventory information increases, as does the cost to obtain this information.

Since many municipalities have limited budgets for performing an earthquake loss estimation study, **HAZUS** accommodates different users with different levels of resources. It should be understood, however, that the uncertainty of the loss estimates increases with less detailed inventory, and that there are uncertainties associated with modules other than inventory. For example, even with a perfectly accurate inventory of soils and buildings in the study area, **HAZUS**, or any other loss estimation methodology, cannot infallibly predict damage and associated losses.

Inventory information will come from and/or be collected in databases compatible with the GIS technology. Once collected and entered into the database, the data can also be made available to users for other applications. For example, data collected for an earthquake loss estimation model in San Bernardino County, California is now being used for city planning purposes.

5.1 Sources of Information

As discussed in Chapter 3, the use of default parameters and default inventory in performing a loss study introduces a great deal of uncertainty. Loss studies performed with only default data may be best for preliminary assessments to determine where more information is needed. For example, an analysis using only default information suggests that the scenario earthquake will cause a great deal of damage in a particular part of your community. You may want to collect more detailed inventory for that area to have a better understanding of the types of structures, the essential facilities and businesses that might be affected. Similarly, your default analysis may indicate that components of your electrical system are vulnerable. Based on this outcome, you may wish to perform walk-downs of the substations to see how they are really configured. In short, it is likely that you will want to augment and update the default data that are supplied with **HAZUS**.

Regional building inventories can be built up from a variety of sources including federal government, state government, local government and private sector databases. These databases may be useful for obtaining facility-specific information. In many cases, information may be plentiful, yet the quality and assembly requirements difficult to assess. Inventory improvements must be balanced with time and budgetary constraints. Request metadata (detailed description and history of the dataset) from information sources, or you may be unable to substantiate the quality of inventories –and loss estimates.

Following are examples of sources of inventory data that can be accessed to enhance the **HAZUS** building data:

- Locations of government facilities, ex. military installations and government offices.
- Databases of hazardous buildings, ex. California Safety Commission database of unreinforced masonry buildings.
- Tax assessor's files
- School district or university system facilities
- Databases of fire stations or police stations
- Databases of historical buildings
- Databases of churches and other religious facilities
- Postal facilities (ATC-26, 1992)
- Hospitals (The AHA Guide of the American Hospital Association; ATC-23A, 1991A)
- Public and private utility facility databases
- Department of transportation bridge inventory
- Dun and Bradstreet database of business establishments
- Insurance Services Office databases used for fire assessment of large buildings.

It should be kept in mind that each of these databases includes only a portion of the building stock, and none is complete. For example, the tax assessor's files do not include untaxed properties such as government buildings, public works and tax-exempt private properties. School district databases probably will not include private schools. A good discussion of available databases is found in Applied Technology Council -13 (1985) and Vasudevan et al. (1992), although some of the databases discussed in these two references are specific to California.

Other possible sources of inventory information are previous loss or hazard studies. An example is "Earthquake Hazard Mitigation of Transportation Facilities" (Allen et al., 1988), which contains a listing of all "seismically significant" points along priority routes surrounding the New Madrid Seismic Zone. This listing includes dams, pipelines, high fills, cut slopes, signs, tanks, mines, faults, bridges, and buildings subject to collapse. This type of list could certainly be used as a starting point for developing a complete lifeline inventory. Unfortunately, many regional loss studies do not contain a listing (either hard copy or electronic) of the inventory that was used.

Mitigation plans can be excellent sources of historical information and references on losses from earthquakes. Each state and local government is encouraged to draft hazard mitigation plans under the Disaster Mitigation Act (DMA 2000, amended), and may be available from state, county, and local government Disaster and Emergency Services. The following sections contain more detailed information about sources of information for specific modules of the earthquake loss estimation methodology.

5.1.1 Potential Earth Science Hazards (PESH)

5.1.1.1 Soil Maps

Soils are defined in geologic terms for the purpose of estimating earthquake losses, as compared to surficial soil definitions. In order to account for the effects of local soil conditions for estimating ground motion and landslide and liquefaction potential, you need to enter a soil map into **HAZUS**. High-resolution (1:24,000 or greater) or lower resolution (1:250,000) geologic maps are generally available from geologists, regional U. S. Geological Survey offices, state geological agencies, regional planning agencies, or local government agencies.

There are a variety of schemes available for classifying soils. **HAZUS** uses the seismic soil type classes recommended by the National Earthquake Hazard Reduction Program (NEHRP). The geologic maps typically identify the age, depositional environment, and material type for a particular mapped geologic unit. You will require the services of a geologist or geotechnical engineer to convert the classification system on your map to the one used in this methodology (see Table A.1 in Appendix A).

If a previous regional loss study has been conducted, you may find that the study contains soil maps. Once again, for use with **HAZUS** you may need to convert the classification to the one described in Table A.1.

5.1.1.2 Liquefaction Susceptibility

Liquefaction susceptibility maps, usable in the hazard analysis, have been produced for a few selected areas, i.e., greater San Francisco region (ABAG, 1980); San Diego (Power, et. al., 1982); Los Angeles (Tinsley, et. al., 1985); San Jose (Power, et. al., 1991); Seattle (Grant, et. al., 1991). Applied Technology Council published a summary of regional liquefaction hazard maps (Power and Holtzer, 1996). Seek out the most current data from state and local government, academic institutions, and online resources.

If no liquefaction susceptibility maps are available, and liquefaction is a potential hazard, a geologist or geotechnical engineer will be required to develop one. The level of effort required depends on the size of the region and the desired resolution of the contours. Soil maps at large scales (1:24,000 to 1: 50,000) provide important source data for developing your liquefaction map, if they are available.

A crude map with a great deal of uncertainty can be developed in a few weeks using the procedure outlined in Chapter 4 of the *Technical Manual*. An experienced geotechnical engineer or hydrogeologist with knowledge of the region can develop a simple map in about one month. A detailed map can require a separate study that could take several months to years. Digitizing a map can take a day to a week depending on the size and complexity of the region. Look for geologic and groundwater maps published in digital format to assist your effort.

5.1.1.3 Landslide Susceptibility

Landslide hazard and susceptibility maps are available from federal land agencies and land planning offices at the state, county and municipal government levels. Increasingly, you will find them available electronically.

If no landslide susceptibility maps are available, and landslides are potential hazards, a geologist or geotechnical engineer will be required to develop one. Transportation departments are excellent sources for landslide hazard information. The level of effort required depends on the size of the region, and the desired resolution of the contours.

5.1.2 General Building Stock

Developing the inventory for general building stock most likely will require combining information from several sources. As mentioned earlier, there is no complete single source of general building stock information. In addition, you will find that the quality and format of the information varies dramatically from county to county. Furthermore, since general building stock inventory is not normally compiled by counting individual buildings, but instead is developed using various assumptions and inferences, you may find that you need input from local engineers and building officials to ensure that you have captured unique aspects of the region.

High quality information may be available, yet difficult to cost-effectively compile. Users will need to balance access to the most accurate and site-specific data with available time and funding resources to develop an acceptable inventory compilation strategy.

As the data sources are diverse and compilation of this inventory is complex, documentation of references used is essential. Also document your assumptions, guidelines, and criteria for making inferences when mapping to the model building types. The building stock inventory improvements may be an on-going task, and inconsistencies in the edit criteria can produce confusing results. The inventory represents trends in construction over time, as well as geographic distribution. Therefore, metadata describing the information sources and lineage of improvements will reap long-term benefits in evaluating the loss estimates as reasonable, or not.

5.1.2.1 County Tax Assessor Files

County Tax Assessor files may or may not be a source of general building stock information. Since Tax Assessor files are kept for the purposes of collecting property taxes, they may contain little or no useful structural information. A comprehensive online directory of Tax Assessors is currently hosted by Northwestern University, Illinois (See http://pubweb.acns.nwu.edu/~cap440/assess.html).

The quality of the data varies widely from county to county. Many counties use Computer-assisted Mass Appraisal (CAMA) systems, which can significantly reduce the data compilation time. Parcel data may already exist in GIS format, which can be useful in making inferences based on spatial patterns.

The most useful data will contain occupancy, structural type, square footage, height, and age. Generally, the files contain good information on the use (occupancy) of the building, since tax rates often depend on building use; therefore, either a land use code and/or a specific occupancy of the building is included.

Ideally, if good information is available, you can use the Building Data Import Tool (BIT) described in Chapter 8 to develop region-specific occupancy to model building type relationships. However, several problems generally occur:

- Square footage: Many Tax Assessor files do not contain building square footage information. In some counties, square footage is not recorded at all. In other cases, it is only sometimes recorded. You should ask the Tax Assessor before you buy the records as to what percentage of the records contain square footage information. Calculation of square footage varies, and should accompany the data source.
- Multiple occupants and owners: Many Tax Assessor files contain square footage information that may be difficult to interpret. For example, a property that is owned by several owners (such as an office building) may appear several times in the files. Perhaps Owner #1 owns two floors of the building and Owner #2 owns eight floors. The Tax Assessor's records may not reflect the fact that Owner #1 owns 20% of the Building and Owner #2 owns 80%. In fact, sometimes both property entries will show the total building square footage instead of Owner #1 with 20% of the square footage and Owner #2 with 80%. Without going through the files record by record, this is difficult to fix.
- Non-taxable entities: Since some occupants that do not pay taxes (e.g., schools, churches, and government buildings) are not usually well represented in the Tax Assessor's files. Often these types of properties include an entry and an Assessor's Parcel Number, but omit assessed value, square footage, structural type, height or age.
- Structure information missing: Structural type may not be recorded at all in the files. You need to ask the Tax Assessor what percentage of the records has structural information before you buy or use the files.
- Year of construction: Similar comments about missing data can be made about age and height.
- Property identifiers: Some or all of the properties in the Tax Assessor's files may contain no address information. In some counties, the Assessor's Parcel Number is the only identifier in the database. While this can be mapped to location, it is not an easy task. The file may contain a mailing address of the owner, but this is not a reliable address to locate properties. Owners do not always occupy their properties and mailing addresses may not correspond at all to the study region of interest. In other cases, selected properties are missing addresses. Property address information is important because you can use addresses to see how the types and occupancies of buildings vary geographically.
- Replacement costs: Construction materials and costs associated with replacement of buildings vary regionally. Value adjustments might require assistance of state or local labor and industry officials, and use of regional economic indices.

- Structure classification schemes: Perhaps one of the most difficult problems is that, in many cases, the Tax Assessors use a system of classifying structures that is difficult to map to the model building types defined in Table A.2.

  For example, there may only be five building types, such as steel frame, wood frame, fire resistant, masonry and other. It is difficult from this very simple classification system to determine whether masonry structures are reinforced or unreinforced. Similarly, it is impossible to distinguish braced steel frames from moment resisting steel frames. Fire resistant construction could include a variety of structural types consisting of concrete or masonry. In these cases you will need to use local experts to help define the mix of construction keeping in mind the purpose of the loss estimates.

5.1.2.2 Commercial Sources of Property Data

There are a variety of online services that maintain databases of real property that are designed to assist realtors and other commercial enterprises in gathering property sales data and owner information, and to assist in generating mailing lists and labels. The databases are developed from County Tax Assessor's files and updated as properties are sold, or as other information becomes available.

You can subscribe to one of these services and download records over a telephone line, or you can order CDs of selected counties and use software supplied by the service to extract the records on your own computer. It seems that different services tend to focus their efforts in different parts of the United States. Therefore, one service may not maintain a database on the county you wish to study while another service may. Typical costs for a county are $300 to $1000, depending on its size. Addresses and phone numbers of several on-line services are listed below. (Note: While these are California addresses, they carry data from around the country. There may be local offices for these companies.)

If one of these services does not have the counties in your study region you may find that there is a service in your own community that maintains these types of records. Local real estate agencies or the local Board of Realtors would probably know about this. Alternatively, you can try calling local Tax Assessors and see if they have sold their data to this type of service.

Some of the Commercial Sources of Property Data are:

Experian Property Data (formally known as TRW)
3610 Central Avenue
Riverside, CA 92506
(800) 345-7334
Website: http://www.experian.com/

First American Corporation
1 First American Way
Santa Ana, California 92707
(800) 854-3643
Website: http://www.firstam.com/faf/services/propinfo-services.html

Transamerica Information Management (offer a program called MetroScan)
1860 Howe Avenue, Suite 455
Sacramento, CA 98525
(800) 866-2783
Website: http://users1.ee.net/megnkate/met-is2.htm

DataQuick Information Services
9171 Towne Centre Drive, #404
San Diego, CA 92122
(800) 950-9171
Website: http://www.dataquick.com/

The commercially available databases contain the same type of problems found in the County Assessor's data since they were obtained from them. One advantage of the commercially available information is that it can be distributed to you in a usable electronic database format. Although the software interfaces vary, each company provides one that enables you to view data on individual properties or to sort properties in a variety of ways (i.e. by zip code, census tract, age, occupancy). On the other hand, assessor's data may be stored on 9-track tape and provide little, or no instruction to extract the data.

One note of caution: Property record selection and downloads are limited to a certain number of records (ex. 9000) at a time. A large county such as Los Angeles contains over two million records. Thus, extracting all of the records for the county can be a tedious task, sometimes taking several days. Requests for data on compact diskette may be most cost-effective.

5.1.3 Occupancy to Model Building Type Relationships

Developing occupancy to model building type mapping schemes that accurately reflect your study region will require combining available data with input from local experts. The Building Data Inventory Tool (BIT) discussed in Chapter 8 has a utility that develops occupancy to model building type mapping schemes from the assessor's files or other commercially available property data. Collecting supplemental information about local building practices through the use of a questionnaire and/or a workshop is recommended.

A questionnaire that was used to collect region specific information for developing some of the default mapping schemes in **HAZUS** is found in Appendix F. This questionnaire was used in a one-day workshop that was attended by about ten individuals with significant experience with local construction that included design engineers, building officials and a university professor. Workshop participants were presented with preliminary occupancy to model building type relationships that were developed from County Assessor's files. Using the questionnaire to focus on the workshop, participants modified preliminary schemes based on their own experience. The advantage of using a workshop instead of sending the questionnaires out was that participants were able to discuss their different opinions and come to a consensus on a reasonable representation of local practices.

5.1.4 Essential Facilities

Essential facilities include hospitals, schools, and emergency services. Many of these are owned or licensed by government agencies. Consequently, lists of these facilities are often available for a region. Facility inventories are typically incomplete and sometimes incorrect; verification of the data with most current information is required. Assignment of the building model type and square footage will depend on the best information available.

The time associated with collecting inventory on essential facilities may be relatively small; perhaps a few days, if no building type information is collected and default occupancy to building type mappings are used. However, more detailed building type information may require a site visit for each facility.

Some essential facilities are subject to special design and construction considerations that may help these structures perform better than the typical building when subjected to an earthquake. Data you collect with respect to special seismic design and construction considerations may be useful later on in identifying whether structures are high-code, moderate-code or low-code design.

The criteria for determining seismic design level categories are summarized in Table 5.1. An additional bias can also be defined for essential facilities to reflect the potential for different damage and losses based on the vintage of the design code. This is described in Section 6.7.1 of the *Technical Manual*.

Table 5.1 Suggested seismic design levels for essential facilities

Seismic Design Level (I = 1.5)	Seismic Zone (1994 Uniform Building Code)	Map Area (1994 NEHRP Provisions)
High-Code	4	7
Moderate-Code	2B	5
Low-Code	1	3

5.1.4.1 Medical Care Facilities

Sources of inventory information for medical care facilities include the yellow pages of the telephone book, city and county emergency response offices, the American Hospital Association and previous loss studies. The default medical facilities database included with **HAZUS** was developed from a FEMA database and contains the number of beds for many of the facilities. Determining the number of beds for other facilities may require the user to contact facilities on an individual basis. Medical care directories of licensed and non-licensed facilities are readily available online and from the county Public Health departments in each state.

5.1.4.2 Fire Stations, Police Stations and Emergency Operations Centers

Locations of fire stations, police stations and emergency operations centers can be obtained from local and statewide disaster and emergency service offices. In addition, many city maps show locations of police and fire stations. Determining the number of fire trucks typically requires the user to contact an administrator in the fire department.

5.1.4.3 Schools

Locations of public schools and their enrollments can be obtained from district offices. The Board of Education in some states compiles a directory of all schools (public and private) in the state with names, addresses, phone numbers and enrollments. The yellow pages and government office pages of your local phone book are general sources. Regional governments often compile directories of local educational institutions (including colleges and universities). The National Center for Educational Statistics[4] is also a resource for information. Verification of data from this, and other secondary sources is recommended.

5.1.5 High Potential Loss Facilities

While High Potential Loss Facilities include nuclear power plants, dams and military installations, default data are currently provided only for nuclear power plants and dams. Military installations will have a program for assessing potential and local hazards. Facility descriptions for estimating study region losses will be subject to allowable release of national security information for that purpose. Requests for information should be directed to the local installation Information Officer.

5.1.5.1 Nuclear Power Plants

HAZUS does not include damage and loss estimates for nuclear power plants. These structures are so complex that estimating losses would require a dedicated study. Instead, only the location of these facilities is mapped in the study region. You will only need to add those nuclear power plants that are not listed in the default database provided with the program. Utilities that operate these facilities will have information on their locations, though they may not be willing to share it. Local, state and Federal regulatory agencies should also have inventories of power plants (e.g. nuclear and fossil fuel plants).

5.1.5.2 Dams

The methodology does not include damage and loss estimates for dams. The default dam database provided with **HAZUS** is a modified version of the NATDAM database supplied by the National Inventory of Dams. It contains over 80,000 entries and includes most of the dams of any significance in a study region, along with descriptive information about each dam. The criteria for inclusion in the database are found in Table 5.2 and the list of fields is found in Appendix E. The default classes that are included in

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[4] Page: 9
Reference: (http://nces.ed.gov/ccd/schoolsearch/)

this database were assigned by converting the rather complex classification system used by NATDAM to the twelve classes used in this methodology.

Cities, counties, states, the Army Corps of Engineers, the U.S. Soil Conservation Service, other federal agencies, water districts, flood control districts, or private parties may own dams or levees. Thus, obtaining more detailed information on dams may require contacting a number of different sources. In addition to the above-mentioned agencies, you may wish to contact the State Office of Emergency Services, local emergency services, fire protection services, or regulatory agencies.

Table 5.2 Criteria for inclusion in the NATDAM database

Characteristic	Criterion	Excluded
Dam Height	Dam height greater than 25 feet	Dam height < 6 feet, regardless of reservoir capacity
Reservoir Size	Reservoir impoundment capacity greater than 50 acre-feet	Reservoir impoundment capacity less than 15 acre-feet maximum capacity regardless of dam height
Hazard	Any dam that poses a significant threat to human life or property in the event of its failure	N/A

5.1.5.3 Levees

Users are responsible for developing their own inventory of levees since **HAZUS** doesn't supply default levee inventory. Levees are defined in terms of endpoints of levee segments (latitude and longitude coordinates). There are a number of fields defined in the levee database structure (see Appendix E) including:

- Levee design basis (for example 100 year flood)
- Levee crest elevation
- Water elevation during most of the year
- Levee owner/operator

Since some levees are designed only to provide protection during flooding, they may be dry during most of the year. These levees may not pose a significant inundation hazard.

5.1.5.4 Military Installations

The methodology includes the capability to estimate damage and loss for facilities on military bases that can be modeled as one of the 36 model building types. Locations of military installations can be obtained from maps or Topologically Integrated Geographic Encoding and Referencing (TIGER) files. These sources give locations of installations but no breakdown as to the number or type of structures. FEMA maintains databases of major Army, Navy and Air Force installations, although they are not included in **HAZUS**.

5.1.6 User-Defined Structures

User-defined structures are those structures, other than essential facilities or high potential loss facilities, which the user may wish to analyze on a site-specific basis. For example, you may wish to identify all of the unreinforced masonry buildings in the community or all of the pharmacies. You can collect data about these types of structures using the same sources you would use for general building stock or essential facilities. Specific databases may be available to you through agency property management offices, state insurance funds, commercial sources of property data, the phone book, interviews with owners, and site visits.

5.1.7 Lifelines

HAZUS includes default datasets from federal agencies for transportation (highway, railway, light rail, bus, port, airport, and ferry) and utilities (electric, gas, potable water, wastewater, gas, oil, and communication). Most of these inventories are minimal. Developing a lifeline inventory or improving the inventories supplied with **HAZUS** most likely will require the cooperation of local utilities or government agencies that operate and maintain the systems. It is difficult to estimate how much time will be required to collect and organize lifeline information because it depends on the size of the region, the level of detail required, the quality of existing data, and the degree of cooperation from utility corporations and agencies within the region.

Previous loss estimation or hazard studies may be sources of information on all types of lifelines. For example, the planning scenarios developed by the California Division of Mines and Geology (CDMG) provide detailed inventories of lifelines and essential facilities (See Davis et al., 1982). In the Davis study, addresses and the number of beds for all hospital facilities are provided. A limitation of the CDMG planning scenarios is that the inventory is only for the area around the epicenter of the scenario earthquake.

Another example of a previous loss study is the study performed for the Portland, Oregon water and sewer systems (Kennedy/ Jenks/Chilton et al., 1989). It should be noted that a detailed lifeline study such as the one performed for Portland might provide information in addition to component inventory. This study contains values of facilities and loss curves (based on MMI[5]) for some components.

In more recent years, New York City Area Consortium for Earthquake Loss Mitigation (NYCEM) has published detailed studies. In the same state, the Multidisciplinary Center for Earthquake Engineering Research, Buffalo, has become a comprehensive source for tracking loss studies. FEMA’s Report 249 (FEMA, 1994) also provides information on loss studies that have been performed. The Association of Bay Area Governments in the San Francisco area and Metro in Portland, have been studying hazard mitigation policies

[5] Modified Mercalli Intensity.

and procedures for quite some time. In some cases their studies have involved developing inventories of local lifeline and essential facilities.

5.1.7.1 Transportation Lifelines

The default databases of highways and bridges included with **HAZUS** were created from data obtained from Federal Highway Administration (FHWA) and the Census Bureau's TIGER files. You may find that the locations of these lifeline components contain omissions and inaccuracies; however, the locations can easily be modified based on more accurate information obtained by the user.

Many states, cities, and counties have invested in GIS systems and may already have computerized databases that you can use. Road centerline files are more often available as maintenance and construction funding is closely tied to transportation inventories. They generally provide the route number, name, road class, and may include street width and average daily traffic. Where road centerline files in GIS do not exist, Computer Assisted Drawing (CAD) files and street maps are two more excellent sources for locating streets and highways. CAD files require spatial transformation of the data; while paper maps will offer a simple scheme for identifying freeways, expressways, main highways, and surface streets. A potential drawback, however, is that to use street maps, you will probably have to digitize them.

To obtain cost and structural information about roads, bridges and tunnels that is not included in the default inventory, local and state transportation agencies maintain lists of bridges and tunnels, and may also have detailed information about their design, construction and configuration. Road engineers are the best source for cost per mile information, if a local agency uses values other than recommended federal guidelines. You may find that you need to perform a survey to collect cost per mile data for roads (surveys are discussed in Section 5.2.)

To obtain information about traffic on road segments you may wish to consult the default bridge database included with **HAZUS**. This database, obtained from the FHWA includes average daily traffic counts. Verify the default data with your regional transportation agency, as the database maintained locally is sometimes more complete and current. As a first step you can assume that the average daily traffic on a bridge is the same as that on a highway leading to that bridge. Alternatively, the public works departments or the city, county, state or the federal agencies that own and operate the roads likely have performed studies with respect to the daily traffic and capacities of the roads.

The Federal Railway Administration maintains databases of railways and associated facilities. In order to improve the default **HAZUS** inventories, you will need to contact the rail companies operating in the study region. These sources should be able to provide structural information as well as cost data.

Light rail, ferry and bus inventories are also part of the default data supplied with **HAZUS**. They are derived from databases managed by programs under the U.S. Department of Transportation and can be improved by contacting the related local operations. In many cases, the data compiled at the federal level came from the local operations, but may be outdated. Verification of the current conditions and cost-replacement values can significantly affect transportation losses.

While the locations of ports and airports are provided in the default inventories, no information is provided about the types of buildings, cranes, tanks, etc. that are at these facilities. The Federal Aviation Administration (FAA) maintains a database of airports along with information about the number of runways and the average daily traffic. It is unclear if you will be able to access this information. Access to this information may require submitting request forms to the FAA and waiting long periods while information security issues are addressed. Facility maps may be obtained from the agencies that operate these ports and harbors. However, it is likely that a phone call and formal written requests to the owner, and possibly a meeting with authorities will be required to get structural and cost information.

5.1.7.2 Utilities Lifelines

Developing a lifeline inventory or improving the default inventories supplied with **HAZUS** generally requires the cooperation of local utilities or government agencies that operate and maintain the systems. In some cases utilities and government agencies are already maintaining databases on GIS systems or in CAD systems. However, the data may have to be converted to a format that is compatible with the ArcGIS software.

More than one supplier may supply water to a region. Suppliers may be either government owned or they may be private companies. Systems may already be mapped in a GIS or CAD system. In this case, the data files may need to be converted to a GIS format. If the water system is not maintained in a GIS, a map of the pipe network can be digitized or scanned for input into **HAZUS**. Similar comments apply to wastewater systems.

A rather crude analysis of water and wastewater systems can be performed by knowing the number of kilometers of different types of pipes for each census tract. Owners of these systems can typically provide this information. If pipeline information is not available from maps or drawings, a surrogate system can be constructed using common alignments with roads and other utilities.

Oil and gas systems consist of not only the pipelines but also refineries, tank farms, pumping plants and compressor stations. In addition to inventories available from suppliers, databases of hazardous waste sites can serve as a locator of fuel storage facilities. Refer to state and local regulatory and monitoring agencies (i.e. water quality, energy) for these data.

5.1.8 Inundation

Sources of existing inundation studies due to dam failure, levee failure or tsunami include state and federal agencies that regulate dams, dam or lake owners, the State Office of Emergency Services (OES), the U.S. Geological Survey (USGS), etc. The availability of such studies may be limited.

If inundation maps are available, they may be digitized and entered into **HAZUS** (see Section 9.2). Digitizing a map for display may take a day to a week. If an inundation map is not available, development of an inundation map for a particular earthquake scenario requires an analysis of the response of the dam to the earthquake and the involvement of a hydrologist to define the extent of flooding. This is a detailed study requiring up to several months.

A crude inundation map can be created from floodplain levels (ex. 100-year flood). Flood Insurance Rate Maps (FIRM), Digital FIRMs, and Q3 Flood Data published by FEMA, or more accurate ones available from local resource agencies will serve this purpose. FIRMs were prepared in the 1970s – early 1980s, and many provide outdated information. Although some flood maps have been improved (DFIRMs, Q3) and meet 1:24,000 mapping standards, they are very general representations of potential inundation areas. You may need to digitize floodplain elevations from the older paper maps, or use several digital flood data files for your study area.

5.1.9 Fire Following Earthquake

Aside from the locations of fire stations, and the number of trucks that should be available from fire departments or regional emergency response organizations, there is little inventory information available to investigate fire following earthquake. Typical wind speeds and wind directions can be obtained from the weather service, and average fire engine speeds should be available from the fire department.

5.1.10 Hazardous Materials

Due to the considerations of limiting the methodology to those hazardous materials whose release could have regional consequences, the default database contains only those chemicals that are considered highly toxic, flammable or highly explosive. In addition, it is limited to those facilities where large quantities of these materials are stored. The Environmental Protection Agency (EPA) compiles an annual inventory of manufacturing facilities that release toxic chemicals into the air, water, and ground. This inventory focuses on 305 chemicals that may cause chronic health problems and serious environmental effects.

The default database was built from the 1993 EPA Toxic Release Inventory (TRI) database of hazardous materials sites. The latest version of the TRI database may be obtained from the EPA. You may opt to use only the information contained in the default database provided with **HAZUS**. This database, however, is limited and you are urged to collect additional inventory for a better representation of the types of chemicals stored in your study region.

The ease with which information regarding hazardous materials storage and usage is available varies from jurisdiction to jurisdiction. Some jurisdictions have this information available in the form of a computer database/printout managed by the municipal fire stations, whereas other jurisdictions do not. Most likely the format of the database will vary from place to place, and even if hazardous materials inventories are easy to get, there will be some effort required to combine databases from several cities in a region.

At the present time, users and handlers of hazardous materials have to meet two primary reporting requirements. One is the requirement mandated by the Uniform Fire Code, and the other is required by the Superfund Amendments and Reauthorization Act of 1986, Title III (SARA Title III). The reporting requirements for each of these are rather different. The Uniform Fire Code is very comprehensive in its coverage. It covers materials that pose any physical or health hazard. The SARA Title III reporting requirements are restricted to 360 hazardous materials that are known to be particularly toxic. These chemicals have been termed Acutely Hazardous Materials (AHM). For either of these reporting specifications, based upon the hazard posed by each material, there are minimum (i.e. threshold) hazardous material quantities, below which the user/handler may store without a permit.

The information contained in the application for a permit is a matter of public record, and the agency granting the permit is able to provide that information to the community, if deemed necessary. The hazardous materials that are covered under SARA Title III, including their Chemical Abstracts Service (CAS) registry numbers, and the threshold quantities for reporting purposes, are listed in Appendix G.

The user should contact the local Fire Department in the case of cities, or the County Health Department in the case of unincorporated areas, to obtain a list of facilities that have obtained permits to store, handle or use hazardous materials. It appears that most jurisdictions within the United States require all users and handlers of hazardous materials to obtain permits from the proper local authority.

The user should also be cognizant of the dynamic nature of hazardous materials data. This will be particularly true of areas that are undergoing economic and industrial growth. For best results, it is strongly recommended that the data be periodically updated, with the update interval being dependent on the rate of growth of the region.

5.1.11 Demographics

Population statistics are used in estimating several different losses such as casualties, displaced households and shelter needs. Population location, as well as ethnicity, income level, age and home ownership is needed to make these estimates. The 2000 Census data are included with **HAZUS**. Population migration patterns, based on place of employment, were developed from Dun and Bradstreet data as described in Section 3.6 of the Technical Manual. The user may be able to obtain updated information from the Census Bureau or from a regional planning agency.

5.1.12 Direct Economic Loss Parameters

Direct economic losses begin with the cost of repair and replacement of damaged or destroyed buildings. However, building damage results in a number of consequential losses that are defined as direct economic losses. Thus, building-related direct economic losses (which are all expressed in thousands of dollars) comprise two groups. The first group consists of losses that are directly derived from building damage:

- Cost of repair and replacement of damaged and destroyed buildings
- Cost of damage to building contents
- Losses of building inventory (contents related to business activities)

The second group consists of losses that are related to the length of time the facility is non-operational (or the immediate economic consequences of damage):

- Relocation expense (for businesses and institutions)
- Capital-related income loss (a measure of the loss of services or sales)
- Wage loss (consistent with income loss)
- Rental income loss (to building owners)

Damage to lifeline and transportation systems causes direct economic losses analogous to those caused by building damage. In this methodology, direct economic loss for lifelines and transportation systems are limited to the cost of repairing damage to the systems and business losses due to cessation of electrical power supply. A large part of the data required to estimate direct economic losses is concerned with the cost of repair and replacement, the value of lost inventory, wages and rent. Many of these types of economic parameters are documented by government agencies.

5.1.12.1 County Business Patterns

County Business Patterns is an annual series published by the United States Census Bureau that presents state and county-level employment, annual payrolls, total number of establishments, and establishments by employee size. The data are tabulated by industry as defined by the Standard Industrial Classification (SIC) Code. Most economic divisions are covered, which include agricultural services, mining, construction, manufacturing, transportation, public utilities, wholesale trade, retail trade, finance, insurance, real estate and services.

The data generally represents the types of employment covered by the Federal Insurance Contributions Act (FICA). Data for employees of establishments totally exempt from FICA are excluded, such as self-employed persons, domestic service employees, railroad employees, agricultural production employees and most government employees.

County Business Patterns is the only complete source of sub-national data based on the four-digit SIC system. The series, therefore, is useful in making basic economic studies of small areas (counties), for analyzing the industrial structure of regions, and as a benchmark for statistical series, surveys and other economic databases. The data can serve a variety of business uses as well as being used by government agencies for administration and planning.

County Business Patterns data are extracted from the Standard Statistical Establishment List, a file of known single- and multi-establishment companies maintained and updated by the Bureau of the Census every year. The Annual Company Organization provides individual establishment data for multi-location firms. Data for single-location firms are obtained from various programs conducted by the Census Bureau as well as from administrative records of the Internal Revenue Service (Census Bureau, 2000).

5.1.12.2 Means Square Foot Costs

The default replacement costs supplied with the methodology (where damage state = complete) were derived from Means Square Foot Costs 2002 for Residential, Commercial, Industrial, and Institutional buildings. The Means publication is a nationally accepted reference on building construction costs, which is published annually. This publication provides cost information for a number of low-rise residential model buildings, and for 70 other residential, commercial, institutional and industrial buildings. These are presented in a format that shows typical costs for each model building, showing variations by size of building, type of building structure, and building enclosure. One of these variations is chosen as "typical" for this model, and a breakdown is provided that shows the cost and percentages of each building system or component.

The methodology also allows the user to adjust costs for location of the structure (i.e., San Francisco versus Dallas). A description of how to estimate costs from the Means publication is found in Sections 15.2.1.1 and 15.2.1.2 of the *Technical Manual*. Since Means is published annually, fluctuations in typical building cost can be tracked and the user can insert the most up-to-date Means typical building cost into the default database. This procedure is outlined in Section 15.2.1.3 of the *Technical Manual*.

For **HAZUS**, selected Means models have been chosen from the more than 70 models that represent the 33 occupancy types. The wide range of costs shown, even for a single model, emphasize the importance of understanding that the dollar values shown should <u>only be used to represent costs of large aggregations</u> of building types. If costs for single buildings or small groups (such as a college campus) are desired for more detailed loss analysis, then local <u>building specific</u> cost estimates should be used.

5.1.12.3 Dun and Bradstreet

Dun and Bradstreet is an organization that tracks all businesses that are incorporated. Dun and Bradstreet maintain data on the type of business, the number of employees, the square footage of the business, the annual sales and a variety of other information. The default square footage for the occupancy classes and for all the census tracts was created from the 2 and 4 digit Standard Industrial Classification (SIC) 1995-1996 Dun and Bradstreet data. This mapping scheme is listed in Table 3.20 of the *Technical Manual*. Dun and Bradstreet will provide aggregated information for a specific region on total number of employees, total annual sales and total square footage by census tract. They can also provide information on specific businesses. Dun and Bradstreet has a helpul online site (http://www.dnb.com/us/), multiple offices in the United States, and can be located using the local telephone directory assistance.

5.1.12.4 Capital-Related Income

The U.S. Department of Commerce’s Bureau of Economic Analysis reports regional estimates of capital-related income by economic sector. Capital-related income per square foot of floor space can then be derived by dividing income by the floor space occupied by a specific sector. Income will vary considerably depending on regional economic conditions. Therefore, default values need to be adjusted for local conditions.

5.1.13 Indirect Economic Loss Parameters

To estimate long-term economic losses (indirect economic losses), you need to supply the variables summarized in Table 5.3. Other inputs will need to be estimated as described below.

Estimates of Supplemental Imports, Inventories (Supplies), Inventories (Demand), and New Export Markets are perhaps the most difficult parameters to estimate. If you have had an earthquake in your region, you will need both pre-quake and post-quake estimates in order to calculate percents as defined in Table 5.3. There are County and Area Development Corporations (CDCs and ADCs) that can provide estimates of local economic activities. However, it is likely you will have to develop estimates of these parameters through discussions with individuals in the local community. One option is to perform a telephone survey. Another option is to create a panel of individuals from all of the sectors in the local community, ask them these same questions and reach some sort of consensus. There are also many universities that have programs, personnel, and resources dedicated to economic research and business development.

Table 5.3 User supplied inputs for indirect economic loss analysis module

Variable	Definition	Units	Default Value
Current Level of Employment	The number of people gainfully employed, by place of work (not residence).	Employed persons	Region-specific
Current Level of Income	Total personal income for the study region.	Million dollars	Region-specific
Composition of the Economy (Level I only)	1. Primarily manufacturing 2. Primarily service, secondarily manufacturing. 3. Primarily service secondarily trade.	1, 2, or 3	1
Supplemental Imports	In the event of a shortage, the amount of a good/service that was supplied from within the region that can be imported from elsewhere.	Percent of current annual imports (by industry)	Defaults for "distinct region"
Inventories (Supplies)	In the event of a shortage, the amount of a good that was supplied from within a region that can be drawn from inventories within the region.	Percent of current annual sales (by industry)	0 (for all industries)
Inventories (Demand)	In the event of a surplus, the amount of a good placed in inventory for future sale.	Percent of current annual sales (by industry)	0 (for all industries)
New Export Markets	In the event of a surplus, the amount of a good which was once sold within the region that is now exported elsewhere.	Percent of current annual exports (by industry)	Defaults for "distinct region"
Percent Rebuilding	The percent of damaged structures that are repaired or replaced	Percent	95%
Unemployment Rate	The pre-event unemployment rate as reported by the U.S. Bureau of Labor Statistics	Percent	6%
Outside Aid/Insurance	The percentage of reconstruction expenditures that will be financed by Federal/State aid (grants) and insurance payouts.	Percent	50%
Interest Rate	Current market interest rate for commercial loans.	Percent	5%
Restoration of function	The percent of total annual production capacity that is lost due to direct physical damage, taking into account reconstruction progress.	Percent (by industry, by year for 5 years)	Defaults for "moderate-major" event
Rebuilding (buildings)	The percent of total building repair and reconstruction that takes place in a specific year.	Percent (by year for 5 years)	70% (yr. 1), 30% (yr. 2)
Rebuilding (lifelines)	The percent of total transportation and utility lifeline repair and reconstruction that takes place in a specific year.	Percent (by year for 5 years)	90% (yr. 1), 10% (yr. 2)
Stimulus	The amount of reconstruction stimulus anticipated in addition to buildings and lifelines repair and reconstruction.	Percent (by industry, by year for 5 years)	0% (for all)

5.1.13.1 Current Level of Employment

You can usually obtain data about current levels of employment from the CDC, state departments of Labor & Industries, local employment offices, and the U.S. Bureau of Labor Statistics. The U.S. Bureau of Labor Statistics can be contacted at:

Bureau of Labor Statistics
2 Massachusetts Ave., N.E.
Washington, D.C. 20212
Phone: 202-606-7800
Fax: 202-606-7797
Website: http://stats.bls.gov/

5.1.13.2 Current Level of Income

You can usually obtain data about current levels of income from the following sources:

- U.S. Department of Census - Bureau of Economic Analysis
- U.S. Bureau of Labor Statistics.
- Area or County Development Corporation
- County and City Employment Offices
- University economic research programs

5.1.13.3 Composition of the Economy

Information about the composition of the economy may be obtained through the County Development Corporation, Governor's Office, Chamber of Commerce, County Commissioner's Office, or the Mayor's office of the largest city in the county.

5.1.13.4 Percent Rebuilding

The percent of destroyed property that is reconstructed will depend on the health of the economy of the region when the earthquake occurs. If there are many vacant properties, there are places for displaced companies and households to move. Thus it is likely that not all of the damaged and destroyed properties will be rebuilt. On the other hand, if the economy is booming and the vacancy rate was very low, then there will be a great deal of competition for space. In this case you can expect that most of the damage will be repaired.

There is no source of data that will directly tell you the percent of destroyed property that will be reconstructed. Centers for economic development are housed at numerous universities, and can often refer you to appropriate data sources. As suggested above, you might use vacancy rates to get a feel for the extra building capacity in your region. However, you will probably want to run the analysis using several values to see how the analysis changes. Reasonable values rebuilding estimates would be in the range of 95% to 100%.

5.1.13.5 Unemployment Rates

You can obtain pre-event unemployment rates from the U.S. Bureau of Labor Statistics and government research and analysis bureaus within the state departments of labor and industry.

5.1.13.6 Outside Aid and Insurance Payouts

Many state governments have an Insurance Commissioner who will most likely have compiled insurance payout statistics for previous disasters in the region. If you have not had a disaster in your region, you may have to contact someone from some other location in the country to ask about payouts resulting from a natural disaster in that region.

In the absence of data, you can run the model twice, once with outside aid set to 100% and once with outside aid set to 0%. This will provide you with lower and upper bounds on the indirect economic impacts.

For state aid statistics, contact the state governor's chief economist at the Office of the Governor. For federal aid statistics contact FEMA either at the main office (in address below) or at a regional office (see Table 5.4):

Federal Emergency Management Agency
500 C. Street S.W., Federal Center Plaza
Washington, D.C. 20472
Phone: 202-646-4600
Fax: 202-646-2531
Website: http://www.fema.gov

Table 5.4 Addresses of regional offices of FEMA

FEMA Region	Address		Phone
Region 1	442 J.W. McCormack POCH	Boston, MA 02109	617-223-9540
Region 2	26 Federal Plaza Room 1307	New York, NY 10278-0001	212-680-3600
Region 3	615 Chestnut Street	Philadelphia, PA 19106	215-931-5608
Region 4	3003 Chamblee-Tucker Road	Atlanta, GA 30341	770-220-5200
Region 5	536 South Clark Street, 6th Floor	Chicago, IL 60605	312-408-5500
Region 6	800 N Loop 288	Denton, TX 76209	817-898-5399
Region 7	2323 Grand Blvd. Suite 900	Kansas City, MO 64106	816-283-7061
Region 8	Denver Federal Center, Building 710, P. O. Box 25267	Denver, CO 80225-0267	303-235-4800
Region 9	1111 Broadway, Suite 1200	Oakland, CA 94607	415-627-7100
Region 10	130 228th St. SW Federal Regional Center	Bothell, WA 98021	206-487-4600

5.1.13.7 Interest Rate

The current market interest rate for commercial loans should be available from a bank, a local newspaper or the Board of Realtors.

5.2 Collecting Inventory Data

It should be understood that many available databases do not contain all of the information that is needed to perform a loss study. For example, they may contain street addresses, the size of the facility, or the value of the facility, but may not contain information about structural type or age. A discussion of inferring missing attributes in inventory databases is found in King and Kiremidjian (1994). Databases may be out of date and may not contain all of the facilities in the region. Databases may be on paper, rather than in electronic format, making them difficult or impossible to use. Combining multiple databases can also be problematic. Issues such as double counting facilities and eliminating unnecessary information need to be addressed (King and Kiremidjian, 1994).

In general, the majority of the building inventory used in the regional loss estimation will not be collected or kept on a facility-by-facility basis. Resource limitations make it difficult to collect such detailed information. Management and storage of such a large amount of information, while possible, is beyond the state-of-practice for many municipalities and government agencies.

Maintaining facility-specific databases will be most useful for important or hazardous facilities such as hospitals, fire stations, emergency operation centers, facilities storing hazardous materials, and high occupancy facilities, to name a few. Procedures exist for supplementing facility-specific databases with area-specific inventory information. An example of an area specific inventory is the number of square feet of commercial space in a census tract or zip code.

These area-specific inventories are often based on economic or land use information that is augmented using inference techniques. For example, the user may have available the number of commercial establishments in a region. Assuming an average size (in square feet) per establishment, the user can infer the total square footage of that occupancy. Similarly, a land use map may be converted to building square footage by multiplying land use area by percent of area covered by buildings (see Section 5.2.2 on Land Use Data).

Techniques for developing inventories by using sidewalk surveys, land use data and aerial photography are briefly discussed below.

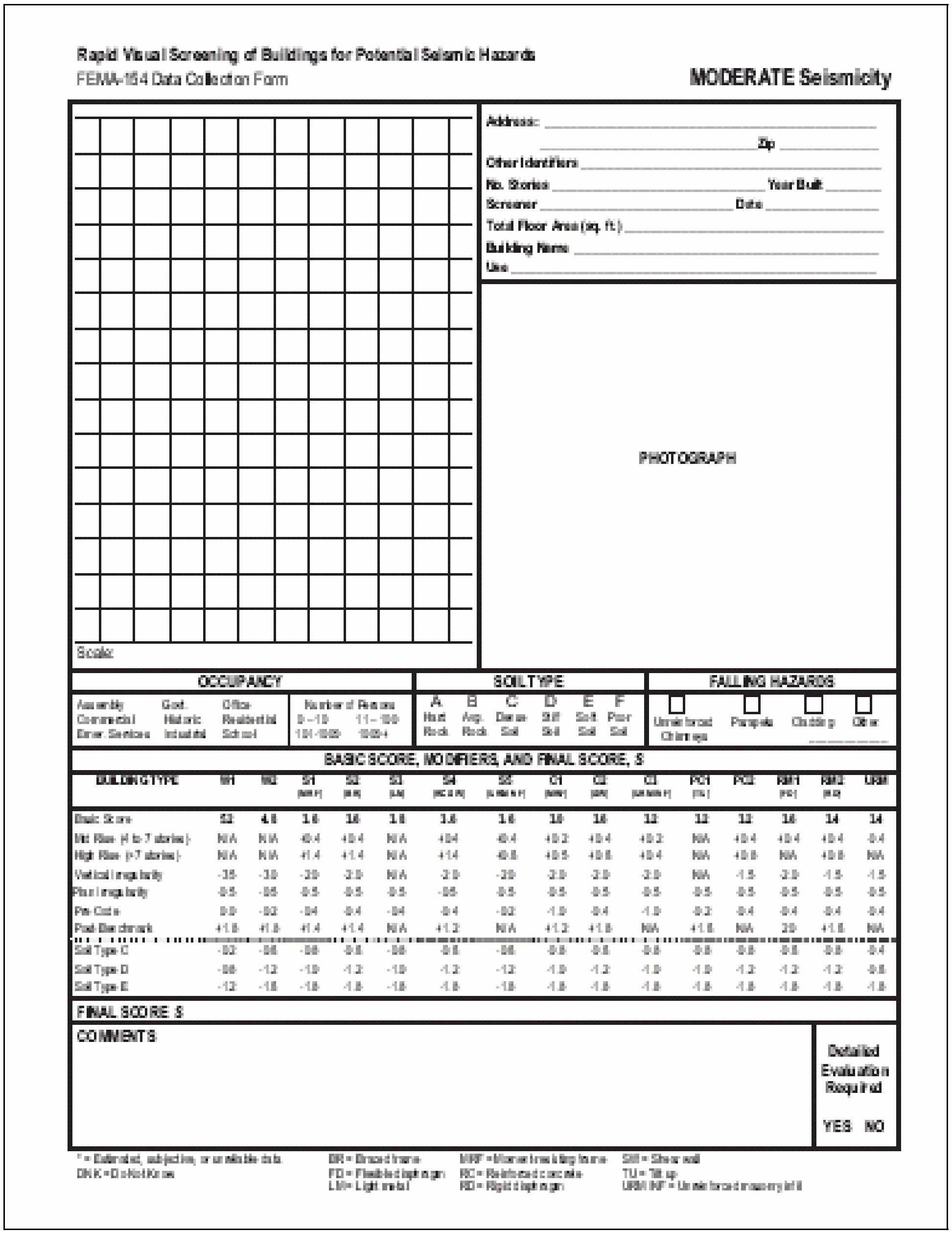
5.2.1 Sidewalk/Windshield Survey

5.2.1.1 What Is Needed:

- Data Collection Sheet
- Map
- Clip Board
- Camera (optional)
- Pre-field Planning
- Your Feet or an Automobile

A sidewalk survey is a technique that can be used to rapidly inventory and identify characteristics of buildings without entering or performing any engineering analyses of the structure. Essentially, most of the inventory collection is done from the sidewalk or the street. An individual uses a pre-defined data collection sheet, a map and possibly a camera and walks or drives through an area to identify buildings and specified characteristics.

A critical aspect of the sidewalk survey is the data collection sheet. An example of a data collection sheet is found in Figure 5.1. This particular data sheet was used for ranking buildings for potential seismic hazards and a scoring system is also included. However, the data sheet could be modified for the needs of the particular region being evaluated.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

MODERATE Seismicity

Address:
Zip
Other Identifiers
No. Stories
Year Built
Screener
Date
Total Floor Area (sq. ft.)
Building Name
Use

PHOTOGRAPH

Scale:

OCCUPANCY: Assembly, Govt., Office, Commercial, Historic, Residential, Emer. Services, Industrial, School. Number of Persons: 0 – 10, 11 – 100, 101-1000, 1000+

SOIL TYPE: A Hard Rock, B Avg. Rock, C Dense Soil, D Stiff Soil, E Soft Soil, F Poor Soil

FALLING HAZARDS: Unreinforced Chimneys, Parapets, Cladding, Other

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	5.2	4.8	3.6	3.6	3.8	3.6	3.6	3.0	3.6	3.2	3.2	3.2	3.6	3.4	3.4
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.2	+0.4	+0.2	N/A	+0.4	+0.4	+0.4	-0.4
High Rise (>7 stories)	N/A	N/A	+1.4	+1.4	N/A	+1.4	+0.8	+0.5	+0.8	+0.4	N/A	+0.6	N/A	+0.6	N/A
Vertical Irregularity	-3.5	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-0.2	-0.4	-0.4	-0.4	-0.4	-0.2	-1.0	-0.4	-1.0	-0.2	-0.4	-0.4	-0.4	-0.4
Post-Benchmark	+1.6	+1.6	+1.4	+1.4	N/A	+1.2	N/A	+1.2	+1.6	N/A	+1.8	N/A	2.0	+1.8	N/A
Soil Type C	-0.2	-0.8	-0.6	-0.8	-0.6	-0.8	-0.6	-0.6	-0.8	-0.6	-0.6	-0.6	-0.6	-0.6	-0.4
Soil Type D	-0.6	-1.2	-1.0	-1.2	-1.0	-1.2	-1.2	-1.0	-1.2	-1.0	-1.0	-1.2	-1.2	-1.2	-0.8
Soil Type E	-1.2	-1.8	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE, S

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Figure 5.1 Example of a data collection sheet for sidewalk survey (Rapid Visual Screening) from FEMA 154.

How the Information is used:

- Develop Inventories of Specific Building Types or Occupancy Classes
- Develop or Check Inferencing Rules
- Check Accuracy of Available Inventories

Sidewalk surveys have been performed in a number of cities. In Oakland (Arnold and Eisner, 1984) and Redlands California (County of San Bernardino, 1987), studies were performed to identify unreinforced masonry or other “seismically suspicious” buildings. In Portland Oregon, a sidewalk survey was used to collect building inventory (about 9000 buildings) for all commercial occupancies in the downtown and surrounding areas. An excellent overview of studies that have been performed using sidewalk surveys or rapid visual screening techniques is found in FEMA 155 (1988).

A sidewalk survey can be used to develop or check inference rules that are used to characterize that region. An example of such rules might be that 90% of all low-rise residential buildings are wood frame and 10% are unreinforced masonry. Data collected in a residential portion of the study region can be compared with the rule to check validity. Similarly, different areas within a region will have different building and occupancy patterns depending on when structures were built, zoning laws and land use. Sampling of different areas within the study region can be used to identify these variations.

Finally, the user may have access to previously collected inventories such as tax assessors files. A sidewalk survey can be used to determine if structural information in the assessors file is accurate.

5.2.1.2 Steps Followed to Perform a Sidewalk Survey

- Define survey objectives
- Develop survey data sheet
- Identify area where survey is to be performed
- Examine map of survey area looking at density of building construction, and other characteristics that would affect how the area is surveyed
- Perform pre-field data collection (e.g. building age)
- Train individuals who will perform survey

As discussed earlier, a sidewalk survey can be performed for a variety of purposes. Examples of survey objectives are:

- Inventory building stock according to occupancy
- Inventory building stock according to model building type
- Identify specific occupancies (e.g. # of buildings on a school campus)
- Identify specific model building types (e.g. unreinforced masonry)
- Identify characteristics of the building stock (e.g. age, height)
- Identify potential seismic hazards (e.g. unbraced parapets, overhangs, unusual geometry)

The design of the survey data sheet will depend on the objectives that are defined. As discussed in FEMA 154, the survey data sheet should include a minimum amount of information as listed below:

- Complete address or other identifier of building (i.e. tax assessor's parcel number)
- Name of surveyor
- Number of stories
- Estimate of building plan dimensions

The above minimum information is needed so that the survey can be updated or used again at a later time. It is also useful for directing any survey related questions to the surveyor. It is also useful to have:

- Sketch of building plan
- Photo of building

A good data sheet will be in a check off format so that 1) all buildings will be in the same format, and 2) the inspector will not forget to mark certain information. One suggestion is to develop data labels from some pre-existing database such as Assessor's files or building department files with street addresses, building type and other information that may be determined before going into the field. Using an Assessor's map to mark down relevant information can also be useful.

Identifying structural types from the street can be extremely difficult. Structural frames and walls are often covered with finishes that mask their characteristics. However, building practices can be associated with certain eras, architectural styles or occupancies. This will likely vary by region. FEMA 154 devotes a whole chapter to inferring model building type from architectural styles. Training of surveyors should include instruction in building practices of the region and characteristics that might be used to identify certain building types. Surveyors should train together on the same group of buildings to improve consistency in survey results.

5.2.2 Land Use Data

Land use data can be combined with a series of inferences to develop a building inventory. This approach has been used in many previous loss studies and is described in some detail in Scawthorn and Gates (1983) and ABAG (1986). Land Use data provides information about the location and area of different land use categories in a region. Several steps are required to convert the land use areas to building inventory:

- Land use must be converted to building type
- Land use area must be converted to square feet of building

To convert land use to building type, inferencing rules about the proportion of model building types in each land use category must be developed. An example of these inferences taken from a loss study for Los Angeles County (Scawthorn and Gates, 1983) is shown in Table 5.5. It can be inferred from this table that if the land use is General Commercial (Code 129), then 23% of the land has 1 to 4 story concrete block construction, 9 % has 1 to 2 story tilt-up, 58% has 1 to 2 story wood, 2% has unreinforced masonry, and 8% has reinforced masonry.

Table 5.5 Land Use to Building Type Conversion - Proportion by Percent
(from Scawthorn and Gates, 1983)

CODE	LAND USE CATEGORY	BUILDING TYPE - STRUCTURAL MATERIAL AND NUMBER OF FLOORS												
		CONC. BLOCK 1-4	TILT-UP 1-2	WOOD 1-2	WOOD 3-4	CONCRETE 1-2	STEEL 1-2	CONCRETE 3-4	STEEL 3-4	CONCRETE 5-19	STEEL 5-19	URM**	REINFORCED MASONRY	STEEL ≥20
111	ESTATE	3		85								4	8	
112	SINGLE FAMILY			87								5	8	
113	DUPLEX / ROW HOUSING			84								11	5	
114	LOW RISE APARTMENTS / CONDOMINIUMS			84								11	5	
115	MEDIUM RISE APARTMENTS / CONDOMINIUMS			75								13	12	
116	RURAL CLUSTERED			89								6	8	
117	RURAL DISPERSED			96								7	4	
118	MOBILE HOMES / TRAILER PARKS	4		92									4	
119	HIGH RISE APARTMENTS / CONDOMINIUMS									69	21		10	
121	MAJOR OFFICE USE	12		10	3	38	7		5		10	3	12	
122*	MAJOR OFFICE USE -- 8 OR MORE FLOORS													
123	REGIONAL SHOPPING CENTER	13	27	4		44		3					9	
124	NEIGHBORHOOD SHOPPING CENTER	13	7	72								1	7	
125	STRIP/ ROADSIDE COMMERCIAL	6		82								6	6	
127	COMMERCIAL RECREATION	18	3	62		6	2						9	
128	HOTEL / MOTEL	16		61	8							3	12	
129	GENERAL COMMERCIAL	23	9	58								2	8	
132	OIL AND GAS EXTRACTIVE	6				3	91							
133	RESEARCH AND DEVELOPMENT	24	18	9		24	18							
134	MOTION PICTURE	27	15	49									7	
135	MANUFACTURING AND ASSEMBLY	15	34	35		7							9	
136	PETROLEUM REFINING / PROCESSING	10	9			4	46	12	13			1	5	
138	MAJOR METALS	5	5			25	65							
139	WHOLESALING AND WAREHOUSING	19	45	5		13	10			3		1	5	
141	AIRPORT	14	15	27		10	15	10				16	8	
142	RAILROAD	7		33		28	11					7	5	
144	HARBOR FACILITIES	4		32		24	28						5	
150	ELECTRIC POWER FACILITIES	10	5			50	25						10	
152	LIQUID WASTE DISPOSAL FACILITIES	25				50	25							
156	COMMUNICATION FACILITIES	32	5	10		40			4		3		6	
160	SPECIALIZED USE INSTITUTION	22		40		19	4	4	4				7	
161	GOVERNMENT OFFICES AND FACILITIES	21		50	3	12						4	10	
162	EMERGENCY RESPONSE FACILITIES	27		27		28							18	
163	MAJOR HEALTH CARE FACILITIES	6		17		47		10	5				15	
164	ELEMENTARY SCHOOL	7		49		16	15						13	
165	JUNIOR HIGH SCHOOL	13		29		37	3						18	
166	HIGH SCHOOL	13		19		38	6	7					17	
167	COLLEGE / UNIVERSITY / OTHER SCHOOL	16	3	5		48	7	4					17	
168	TRADE SCHOOL	16		27		32	3					1	21	
169	RELIGIOUS FACILITIES	16		42		21	3					2	16	

* Code 122 was distributed amongst building types concrete, 5-19; steel, 5-19; and steel ≥ 20 using a method described in Section 2.4.1.3.1.
Land Use Code 122 was the only one with any of its total area assigned to the steel ≥ 20 building type.

** All of the area assigned to Unreinforced Masonry (URM) was distributed according to a method described in Section 2.4.1.3.2.

This table was developed based on interviews with experienced engineers and personnel from local building departments. Using the standardized model building types developed in this methodology, concrete block would be classified as reinforced or unreinforced masonry. You will need to discuss with a local building official or other expert whether or not the concrete block construction contains reinforcing.

To estimate square footage of each building type, one needs to make inferences about the ratio of building square footage to total land. An example of this type of inference is found in Table 5.6. This table, also taken from Scawthorn and Gates (1983), was developed with the help of real estate consulting services, the local school district, and experienced engineers. Table 5.6 shows that for land containing high-rise apartments (Code 119), the square footage of the apartment is equal to 184% of the land area; whereas, for single family dwellings (Code 112), the square footage of these dwellings is only 18% of the land area. For example, if 4 acres of land contain high-rise apartments and 3 acres contained single-family dwellings, the following inventory results:

4 acres x 43,560 sq. ft/acre x 1.84 bldg. sq. ft/sq. ft = 320,600 sq. ft high rise apartments
3 acres x 43,560 sq. ft/acre x 0.18 bldg. sq. ft/sq. ft = 23,522 sq. ft single family residences

These numbers can then be proportioned among building types using the inferences in Table 5.5. The results are shown in Table 5.7.

Table 5.6 Site coverage for different land use categories

CODE	LAND USE CATEGORY	FLOOR AREA RATIO (%)
111	ESTATE	23
112	SINGLE FAMILY	18
113	DUPLEX / ROW HOUSING	25
114	LOW RISE APARTMENTS / CONDOMINIUMS	48
115	MEDIUM RISE APARTMENTS / CONDOMINIUMS	100
116	RURAL CLUSTERED	4
117	RURAL DISPERSED	5
118	MOBILE HOMES / TRAILER PARKS	25
119	HIGH RISE APARTMENTS / CONDOMINIUMS	184
121	MAJOR OFFICE USE	80
122*	MAJOR OFFICE USE -- 8 OR MORE FLOORS	200
123	REGIONAL SHOPPING CENTER	30
124	NEIGHBORHOOD SHOPPING CENTER	28
125	STRIP/ ROADSIDE COMMERCIAL	40
127	COMMERCIAL RECREATION	35
128	HOTEL / MOTEL	70
129	GENERAL COMMERCIAL	35
132	OIL AND GAS EXTRACTIVE	2
133	RESEARCH AND DEVELOPMENT	35
134	MOTION PICTURE	20
135	MANUFACTURING AND ASSEMBLY	65
136	PETROLEUM REFINING / PROCESSING	5
138	MAJOR METALS	50
139	WHOLESALING AND WAREHOUSING	60
141	AIRPORT	5

142	RAILROAD	5
144	HARBOR FACILITIES	30
150	ELECTRIC POWER FACILITIES	10
152	LIQUID WASTE FACILITIES	2
156	COMMUNICATION FACILITIES	5
160	SPECIALIZED USE INSTITUTION	15
161	GOVERNMENT OFFICES AND FACILITIES	60
162	EMERGENCY RESPONSE FACILITIES	50
163	MAJOR HEALTH CARE FACILITIES	80
164	ELEMENTARY SCHOOL	25
165	JUNIOR HIGH SCHOOL	23
166	HIGH SCHOOL	33
167	COLLEGE / UNIVERSITY / OTHER SCHOOL	25
168	TRADE SCHOOL	30
169	RELIGIOUS FACILITIES	30

*The amount of area in Land Use Code 122 was distributed according to a method described in Section 2.4.1.3.1 and this Floor Area Ratio was used only as a check against the estimate.

Table 5.7 Square footage of each building type for study region

	Wood (1-2 stories)	Unreinforced Masonry	Reinforced Masonry	Concrete (5-19 stories)	Steel (5-19 stories)
High Rise Apartments	-	-	32,060	221,214	67,326
Single Family Residential	20,464	1,176	1,882	-	-

Land use information can be obtained from Land Use and Land Cover maps and digital data available from the USGS, or from maps developed by local counties and cites. It should be understood that the resolution of USGS maps (1/100,000 or 1/250,000 scale) might not be adequate. Some of these maps are based on aerial photography from the mid-1970s and have not been updated. As a result, they may not contain newer developments. Check the aerial photography source date before using these maps. An index of available maps and digital data can be obtained from the USGS.

A mix of higher resolution landuse data and mapping has been completed, or is in-progress by many counties and watersheds in the U.S. for planning purposes. Some municipalities maintain their own land use maps or computerized land use databases. Increasingly, landuse datasets are available online from local GIS programs around the country.

5.2.3 Aerial Photography

Aerial photography may be most useful for developing land use maps in areas where they do not already exist. A great deal of research has been done on how to convert aerial photographs to land use maps (Gauchet and Schodek, 1984; Johnson, 1986; Jones et al., 1987). The effort involved is significant; therefore, other methods of collecting inventory may be more appropriate.

5.2.4 Discussions with Local Engineers and Building Officials

Valuable information, particularly on age and type of construction, can be collected from discussions with engineers, building officials and inspectors. Past experience has shown that the best data collection occurs if interviews are conducted in an organized and consistent manner. In a loss study by the Association of Bay Area Governments (ABAG, 1986) typical interviews lasted 1 to 3 hours and involved filling out a form such as the one shown in Figure 5.2. It was discovered in the interview process that building officials who had been working and living in the region for a number of years could provide much more information than those who were new to the region. In addition, building officials could provide little information about facilities for which they have no jurisdiction - these included public schools, hospitals, state colleges and universities, state penitentiaries and federal military installations.

To develop the occupancy to model building type relationships used in this methodology, several one-day workshops were performed around the country. These workshops were comprised of building officials, engineers and academics. Appendix F contains an example of a questionnaire that was used to better understand the characteristics of the regional building stock.

TABLE B-1-
PERCENTAGE OF SELECTED BUILDING TYPES
WITHIN LAND USE CLASSIFICATIONS

CENSUS TRACT NO.________ JURISDICTION:________	IS TRACT SPLIT:________ OTHER JURISDICTIONS: ________ ________			TRACT POPULATION:________ TRACT POPULATION IN JURISDICTION:________ TRACT EMPLOYMENT:________		
LAND USE	WOOD FRAME (%)	LIGHT METAL (%)	MASONRY (%)	CONCRETE AND STEEL (%)	PRE-CAST CONCRETE (%)	MOBILE HOME-TYPE (%)
11 RESIDENTIAL						
(111) 1 or less Du/acre						
(112) 2-8 Du/acre						
(113) 9 or more Du/acre						
(114) Mobile Home Parks						
12 COMMERCIAL & SERVICES						
(121) Retail & Wholesale						
(122) Commercial Outdoor Recreation						
(123) Education						
(1231) Elementary & Secondary						
(1232) Colleges & Universities						
(1233) Stadium						
(124) Hospitals, Rehab Centers, Other Public Facilities						
(125) Military Installations						
(126) Other Public Institutions and Facilities						
(1261) Stadium						
(1262) Church						
(127) Research Centers						
(128) Office						
(129) Hotels						
13 INDUSTRIAL						
(131) Heavy Industrial						
(132) Light Industrial						
14 TRANSPORTATION UTILITIES						
(141) Highways						
(142) Railways						
(143) Airports						
(144) Ports						
(145) Power Lines						
(146) Sewage treatment plants						
15 COMMERCIAL AND INDUSTRIAL						
16 MIXED URBAN OR BUILT-UP LAND						
(161) Transitional						
(162) Mixed use in buildings						
17 OTHER URBAN OR BUILT-UP						
(171) Extensive recreation						
(1711) Golf Courses						
(1712) Racetracks						
(172) Cemeteries						
(173) Parks						
(174) Open space-urban						
NON URBAN						
(233) Greenhouses						
(55) Sedimentation ponds						
(75) Mines, quarries and gravel pits						
(761) Sanitary land fills						
Comments:						

Figure 5.2 Association of Bay Area Governments (ABAG) survey

Chapter 6. Entering and Managing Data in HAZUS

HAZUS contains a variety of default parameters and databases. You can run a loss estimation analysis using only default data (Chapter 3), but your results will be subject to a great deal of uncertainty. If you wish to reduce the uncertainty associated with your results, you can augment or replace the default information with improved data collected for your region of study.

HAZUS contains two import tools for entering data: the stand-alone Building Information Tool (BIT)[6] for improving general building stock (discussed in Chapter 8), and the Inventory import menu option for entering site-specific (ex. hospitals, schools) and hazard data (ex. liquefaction, landslides). Data which has not been imported can still be used as overlays and for general spatial queries, but will not be treated in the loss estimation model.

As has been discussed in earlier sections, it is very likely that data obtained from different sources will not be in the same format. Furthermore, the data may contain a different number of fields than the data defined in **HAZUS**. This will require mapping the data fields to the correct format and inclusion in the centralized geodatabase. The following sections describe importing data, entering data through **HAZUS** windows, and managing the data.

6.1 Importing Features and Files

Only some offices and potential **HAZUS** users will have the most current version of GIS software; others will not currently use ESRI software. Those who have previously applied **HAZUS®99** for Level II analysis will recognize the similarity of data field headers and inventory requirements. All operators of **HAZUS** will be starting with the newest default datasets; first to be evaluated, and then improved by directly editing the default inventories, or by importing new data files. Data that are not already formatted in GIS will require conversion to the standardized ESRI ArcGIS geodatabase format before importing.

6.1.1 Importing Site-Specific Data Files

Arcview shapefiles, ArcInfo coverage files, CAD files, image files, and tabular database files (e.g. Paradox, dBase) must be converted to a geodatabase (*.mdb) for use with **HAZUS**. Several file types (e.g. shapefile, drawing, tabular) may be converted to one or more geodatabases for import. MapInfo, Atlas, or other CAD file formats will generally require exporting files to a shapefile format in order to bring them into ArcGIS. Images or files designated for reference only can still be added as a simple layer for use in

[6] BIT is a deprecated tool and is being replaced by CDMS (Collection Data Management System)

displays, and need not be imported. Data intended for consideration by the loss estimation model must be imported. ArcCatalog or ArcMap can be used for this purpose.

Select the inventory you wish to improve from the **HAZUS** Inventory menu and begin editing (see Figure 6.1). Using the mouse, left-click on a record, then right-click and choose "Start Editing". Now that you are in the edit mode, "Import" will appear in bold when you right-click the mouse (Figure 6.2). Enter the directory and filename for the database you wish to import, as in Figure 6.3.

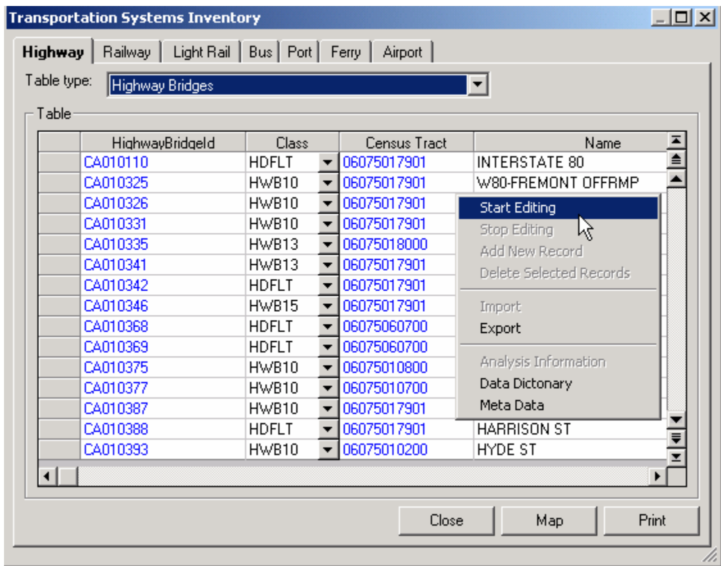


Figure 6.1 Start editing to import data.

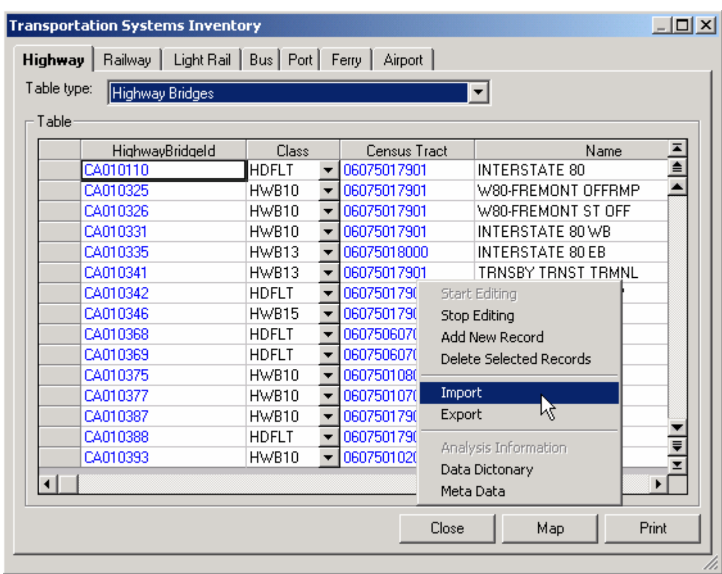


Figure 6.2 Import features with attributes.

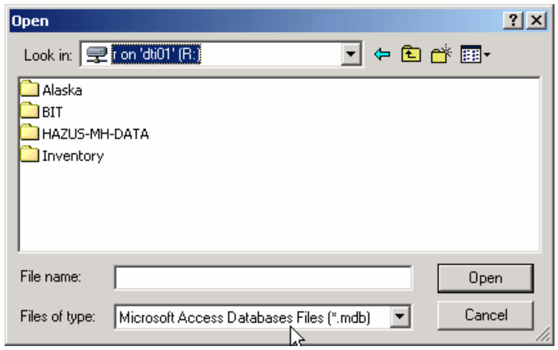


Figure 6.3 Identify the database to be imported.

6.1.2 The Import Database Utility

A database import utility has been developed to assist you in converting an electronic database to the appropriate format for **HAZUS**. Clicking on the right mouse button accesses this import utility. Select the **Import database** and click on the name of the file you want to import; click the **OK** button.

The mapping window shown in Figure 6.4 is used to map the each field in your database (the source) to the corresponding field used in the **HAZUS** database (the target database). The Database Dictionary in Appendix E contains the names and structures of all of the databases that are used by **HAZUS**. From the Database Dictionary you can determine the names of the target fields. The Database Dictionary, in an abbreviated, form is available interactively in **HAZUS**. To access it, click on the right mouse button; using the same menu shown in Figure 6.2, click on **Dictionary**. An example from the Database Dictionary is shown in Figure 6.5.

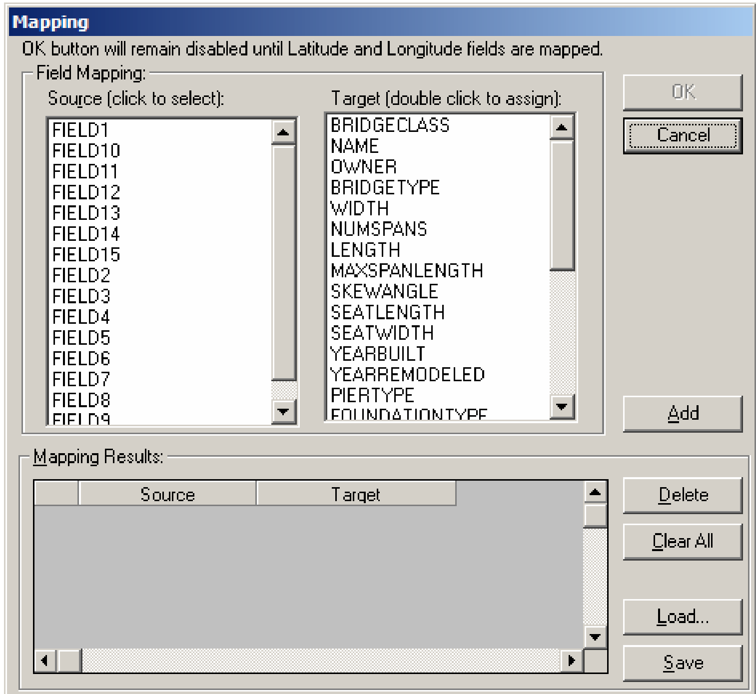


Figure 6.4 Mapping the fields of your data file to the HAZUS data structure

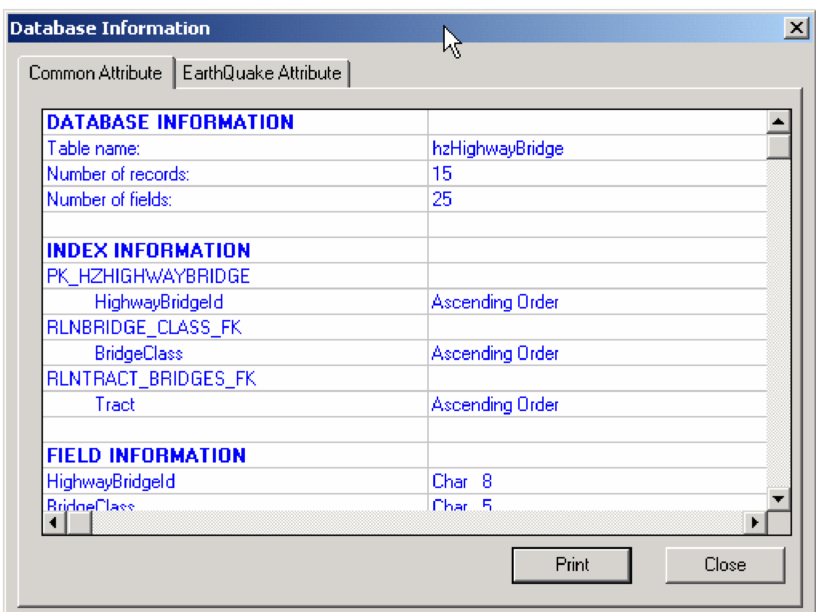


Figure 6.5 Interactive database dictionary.

The fields from the **Source** menu do not have to be in the same order nor do they have to have the same names as the fields in the **Target** menu. To define the desired mapping scheme, simply click on a field name from the **Source** menu (e.g. LON) and the corresponding field name from the **Target** menu (e.g. Longitue); then click on the **Add** button.

After performing these steps, the mapping you have defined will disappear from the **Source** and **Target** menus and will appear in the **Mapping Results** box at the bottom of the window. If you make a mistake, click the **Delete** button, and the last mapping pair you have defined will be undone. In this example, the user has already defined six relationships and is in the process of defining a seventh. When you have completed defining all of the information, click on the **OK** button, wait a few seconds, and your imported database will be displayed in **HAZUS**. You do not have to map all of the fields from the **Source** menu. However, any fields you do not map will not be imported into the **Target** database.

It is possible to have several databases with the same format. To save the mapping that you have defined so that it can be reapplied to other files, click the **Save** button in Figure 6.4 and the dialog box shown in Figure 6.6 will appear. Enter a name for the mapping scheme and click the **OK** button. To retrieve the saved mapping, click on the **Load** button in Figure 6.4.

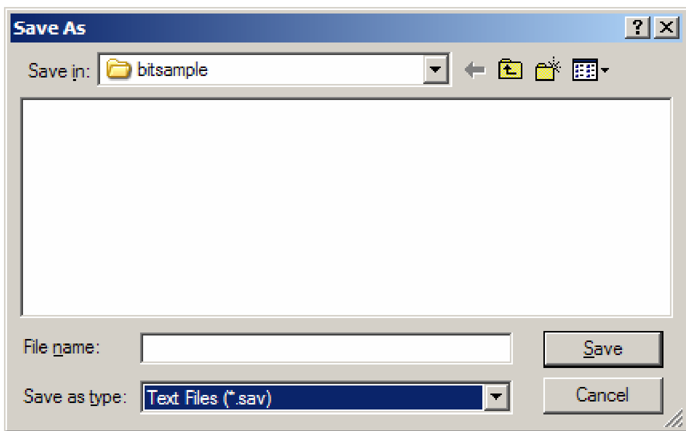


Figure 6.6 Saving a database mapping scheme.

6.2 Adding Records to Site Specific Databases

In addition to importing entire datasets, you can add one or more site-specific (point) feature records at a time to improve inventories of essential facilities, high potential loss facilities, lifeline components and facilities storing hazardous materials. When you identify a new site, you will need to add a new feature record with attributes.

6.2.1 Adding Features Using the Study Region Map

You will notice that feature locations are listed in the ArcMap attribute table without the entire set of feature attributes. **HAZUS** stores attributes other than the each feature identifier and coordinates using SQL Server. This design for feature and attribute storage is for efficiency, and allows for anticipated expansion to interactive web-based delivery of the program. The database design requires you to add features in the following steps:

1. Map the table you want to edit.
2. **Start Editing** using the ArcMap Editor toolbar.

3. Select the appropriate and available database (e.g. util.mdb for editing utility facilities).
4. Add features[7].
5. Select **Stop Editing** features from the Editor toolbar when.
6. Open **HAZUS** Inventory menu and select the appropriate inventory (e.g. utilities).
7. Add attributes to each new feature record by placing the cursor in the desired field.

   Notes:
   a. The feature ID field cannot be edited.
   b. Several fields include a pick list for standardized data entry (see Figure 6.10)

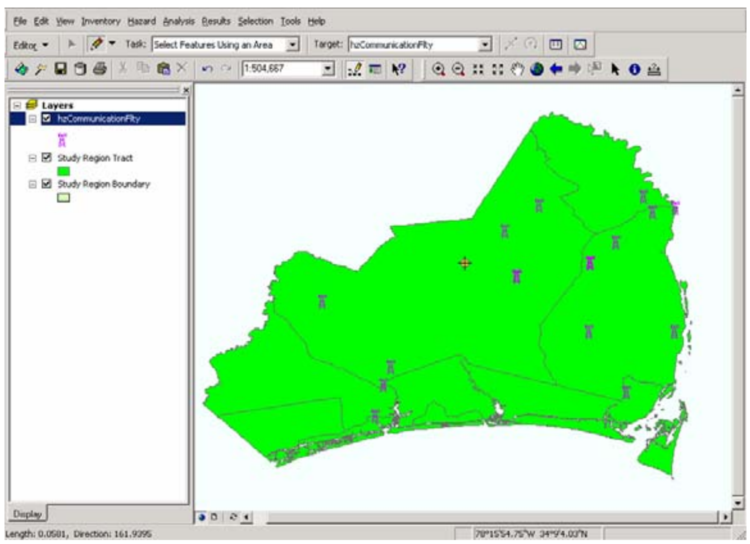


Figure 6.7 Add site-specific feature.

[7] Editing using the **Editor** toolbar is a standard ArcMap. Refer to ArcMap's documentation and online help for details.

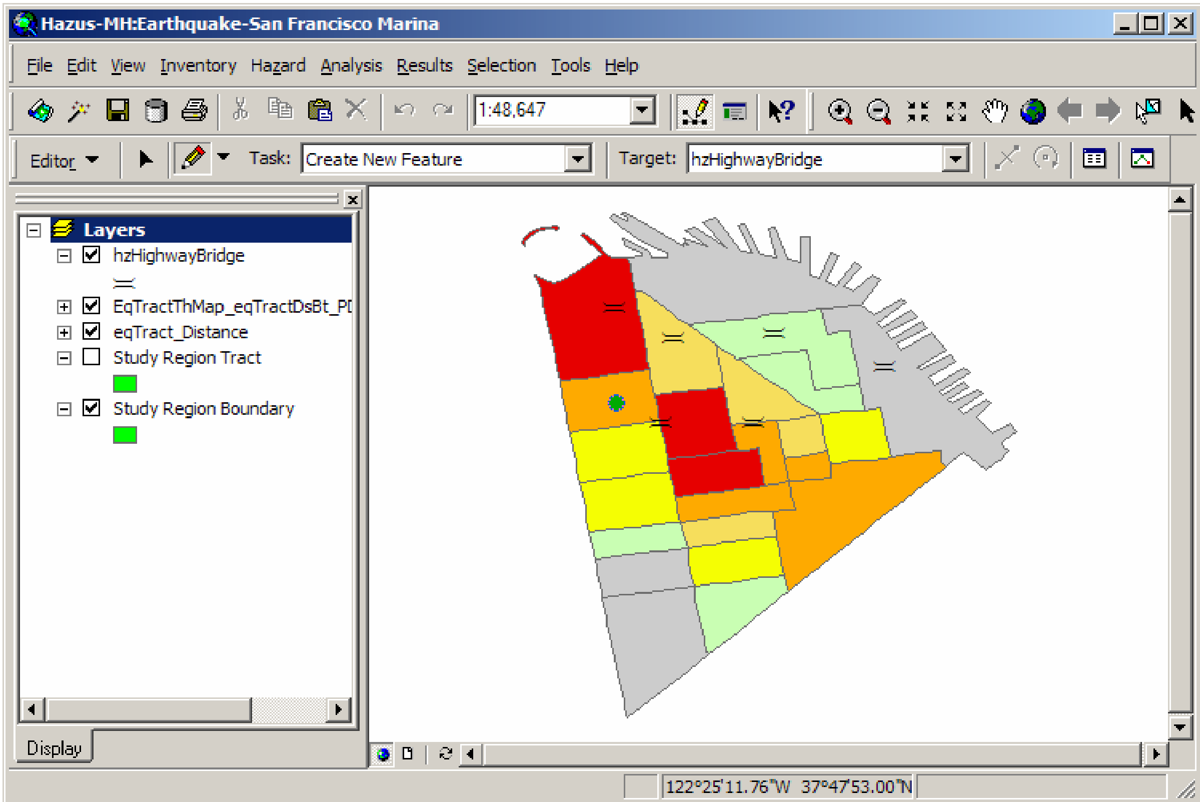


Figure 6.8 Add feature using ArcMap edit tool.

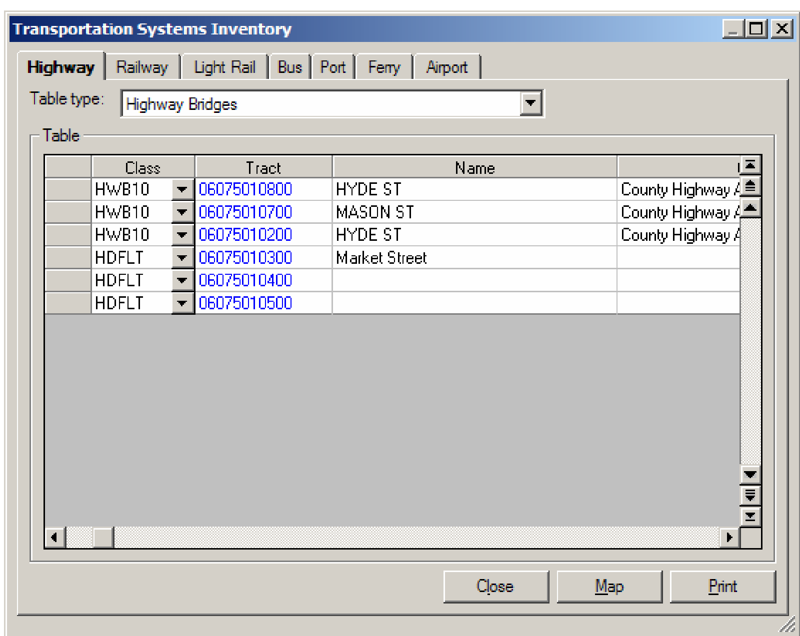


Figure 6.9 Add attributes under HAZUS Inventory menu.

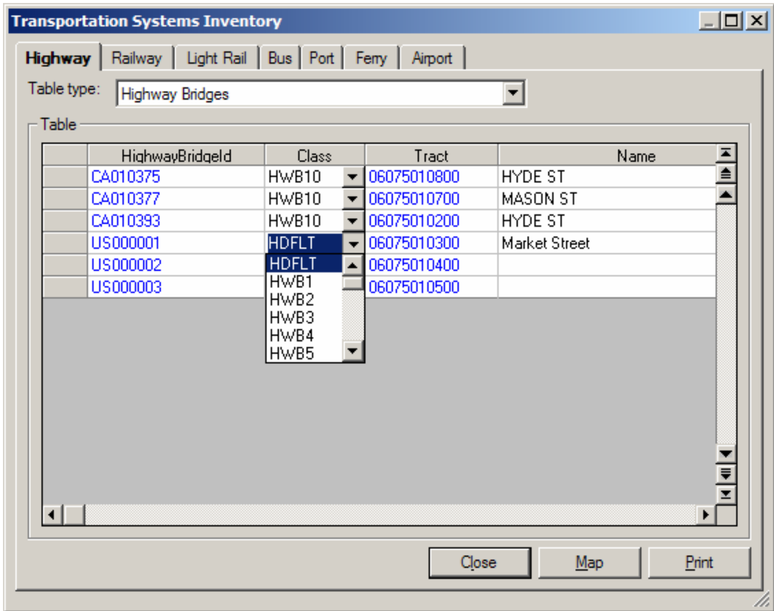


Figure 6.10 Use attribute pick lists where available.

The site-specific, or facility inventories have many more data fields than are required for estimating potential losses. The additional information is beneficial to the overall analysis, and cost-efficient to collect along with the minimum data required running **HAZUS**. At minimum, the required fields for each database are specified in Appendix E[8]. **HAZUS** will create automatically a unique ID to identify uniquely the record[9].

6.2.2 Adding Records to the Attribute Table

The one essential datum element ***required*** to define a facility is its location. If its location was not added graphically (see Figure 6.7), the only other way to define a facility location in **HAZUS** is to type the longitude and latitude of the facility, as in Figure 6.11. If you don't know the longitude and latitude of the facility, you will need to use a geocoder[10] to get the longitude and latitude of the location and then add it to the database in **HAZUS**. Once you have defined a location, click on the **OK** button and the new point feature will be saved.

[8] Required fields are labeled as *mandatory* fields in the data model. While required, in most cases the data model has *default* values assigned as shown also in the data model in Appendix E.
[9] For user-input data, the ID is in the format USnnnnnnnn, where n is sequential number. For the default data, the first two characters are the state code (CA, DC, GA, etc.)
[10] The geocoding process is performed outside HAZUS® Any commercial geocoder application can be used.

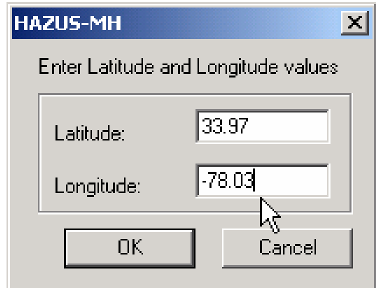


Figure 6.11 Add Record latitude/longitude coordinates.

When the location has been entered, a default set of attributes will be assigned to each new record, in the event no other detail is available. For example, **HAZUS** assumes a generic default bridge class of HDFLT if no bridge class is supplied. To complete the new records using improved information, fill in the required fields using the pick lists provided for standardized data entry (see Figure 6.10). Complete the data fields that do not have a pick list with the best available information.

To save the new added records to the database, right-click and select **Stop Editing**. **HAZUS** will prompt for confirmation and will save then the data to the hard-disk.

6.2.3 Errors When Adding Records

HAZUS is very strict about enforcing the rule that *all inventory data points must fall within the study region boundary*. If you define facility locations that are outside the study region, **HAZUS** deletes them and displays the dialog show in Figure 6.12.

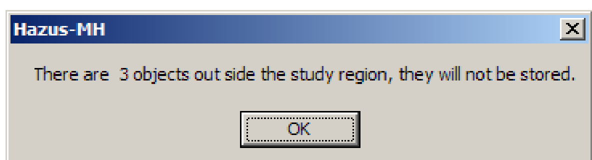


Figure 6.12 Sites added outside the study region will not be accepted.

6.3 Deleting Records from Site Specific Databases

Select the record to be deleted from a database by clicking on the record marker on the left side of the record ID. When the records have been selected, use the right mouse button to display the database management options shown in Figure 6.13, and choose **Delete Selected Records**.

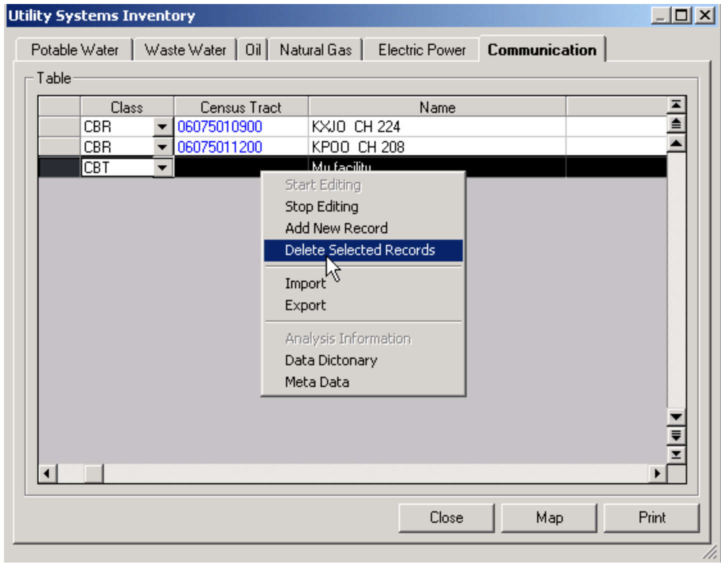


Figure 6.13 Select and delete records from a facility database.

6.4 Editing Records

Attributes associated with default, or improved point and line features can be edited directly in **HAZUS**. Open the **HAZUS** menu **Inventory** and choose the database to edit. Right-clicking the mouse on the spreadsheet, placing the cursor in the desired cell, and replacing the text to be modified can edit data within a record. In order to minimize errors, use the pick lists to fill in the value whenever a list is offered (see Figure 6.10)

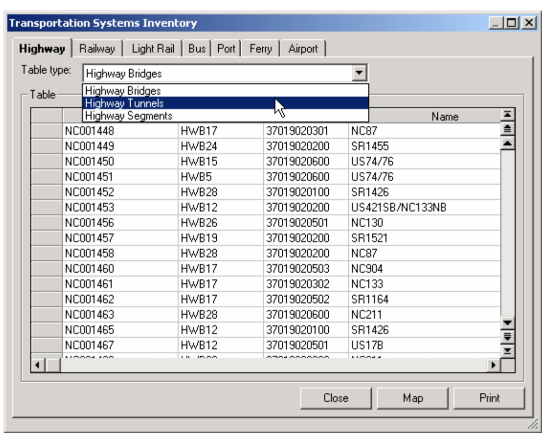


Figure 6.14 Edit default inventory.

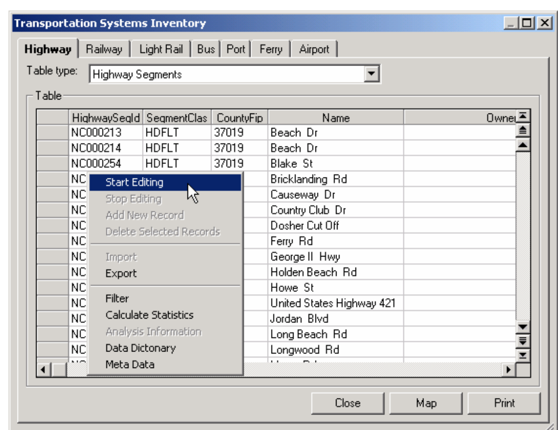


Figure 6.15 Menu option to start editing.

Alternatively, a facility's location can be moved by choosing **Start Editing** from the ArcMap **Editor** toolbar. In edit mode, use one of ArcMap's selection buttons to isolate the facility of interest. With your feature selected and mouse button held down, drag and drop the facility symbol from its old location to the desired new location. To delete a location, select the facility on the map and press the <**Delete**> key. The feature and all associated attributes in the inventory database will be deleted.

You can move or delete multiple records at one time. To do so, use the ArcMap selection tools to select by location. You can draw a box around several sites to select a group; or, select a single structure by clicking on each location, one at a time, while holding the <**Shift**> key down. When all the locations have been selected, release the <**Shift**> key and follow the above steps for deleting or moving a record. When finished, click on the **Editor** toolbar and select **Stop Editing**. You will be asked to confirm (or dismiss) your changes to the database.

6.5 Adding Lifeline Segments

Lifeline segments must be created using ArcMap **Editor** tools. To add lifeline segments (ex. highway, railway, light rail, etc.) you must be familiar with the functionality of the "Editor" in ArcMap. Refer to the ArcMap documentation for details.

6.6 Specifying Hazard Maps

Simplified hazard maps are generated during the creation of the study region. These crude hazard maps are based on default soil maps and the census tract boundaries and can be modified by a user that has a general understanding of spatial distribution of the hazards. If digital information is available from experts or other state agencies, the expert-generated maps should replace the simplified maps. Refer to **Appendix K** for instructions about how to convert shape file based hazard maps to corresponding GeoDatabases based hazard maps that could be used with **HAZUS**.

Define hazard soils under the **HAZUS** menu **Hazard / Senario**. The wizard shown in Figure 6.16 will guide you through the choices to reset the default soil hazard value of the primary soil map (NEHRP). You will also have an opportunity to reset the default values assigned to liquefaction, landslide, and water depth; or, to enter an improved map for each.

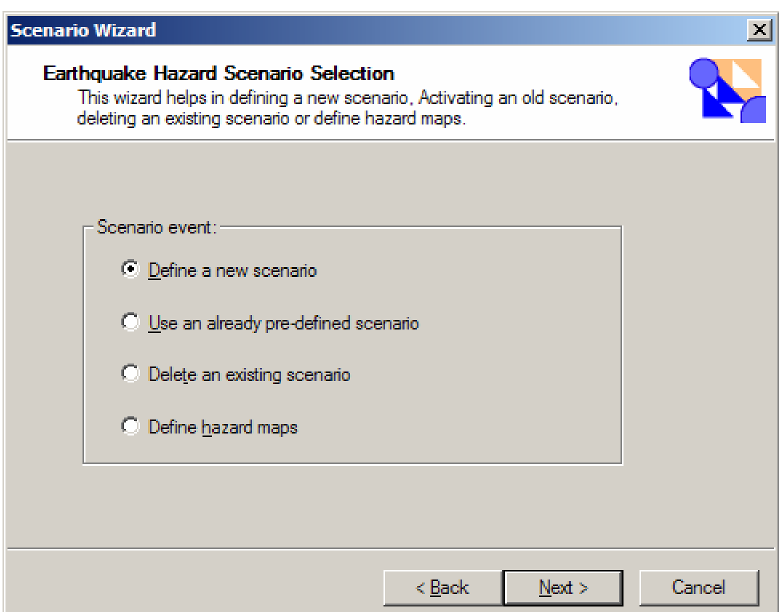


Figure 6.16 Define earthquake hazards maps.

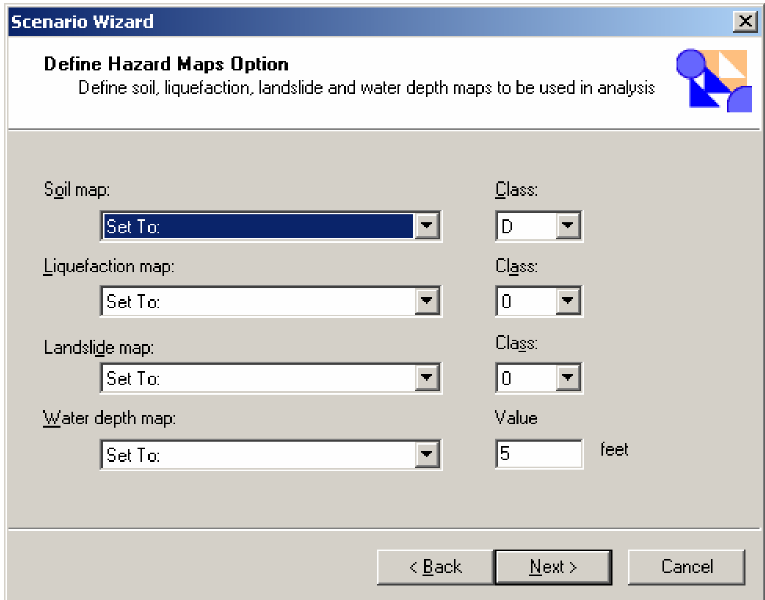


Figure 6.17 Select soil hazard values, or use improved hazard maps.

Soil, liquefaction susceptibility and landslide susceptibility maps listed in the 'Define Hazard Maps Option) shown in Figure 6.17 are input through the **Hazard|DataMaps** menu. To add a file, either type the path name in the provided box, or click on the button to the right of the box. This button will access a standard "Open" window. Move around the directories to find the needed file. Remember, hazard data, like all other data used in **HAZUS** must be in geodatabase format (*.mdb).

When hazard data have been added, you will be able to choose among them for use in an analysis. The window in Figure 6.18 tracks the addition and use of each hazard map, and is available from the menu **Hazard|Data Maps**. Figure 6.19 confirms the replacement of the default liquefaction map with improved data.

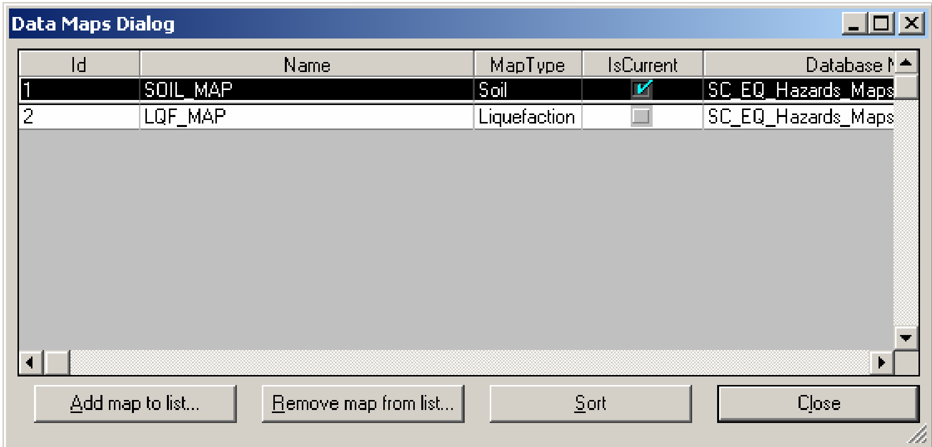


Figure 6.18 HAZUS Data Maps Dialog.

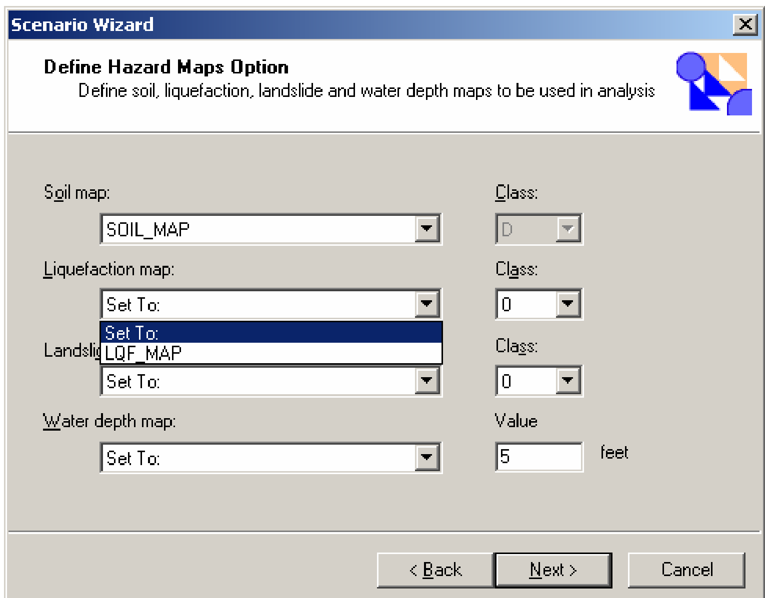


Figure 6.19 Improved hazard maps can replace default hazard maps.

6.6.1 Modifying Hazard Maps

The default earthquake hazard maps can be modified by directly entering the newly desired default value or class as in Figure 6.20. If information derived from local sources suggests the default data do not represent actual conditions, yet improved hazard maps are not available, the site class of each hazard for the study region can be changed. These modifications may also be considered as part of a model sensitivity analysis.

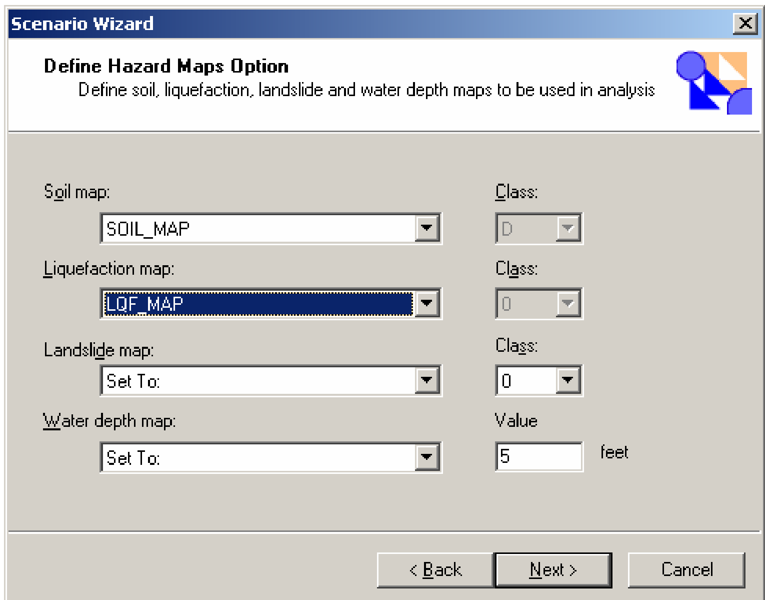


Figure 6.20 Default hazard maps can be modified.

Chapter 7. Displaying, Modifying and Mapping Inventories

Chapter 6 discussed how to enter data and import databases. Once your data is entered into **HAZUS**, you have a number of options available for displaying and modifying the data.

7.1 Editing a Database

Data within a database can be edited by double clicking on the spreadsheet cell containing the data you want to change. Highlight the text you wish to modify and your typing will replace the highlighted text.

7.2 Printing a Database

All databases can be printed to hardcopy using the **Print** button at the bottom of the window (see Figure 7.1).

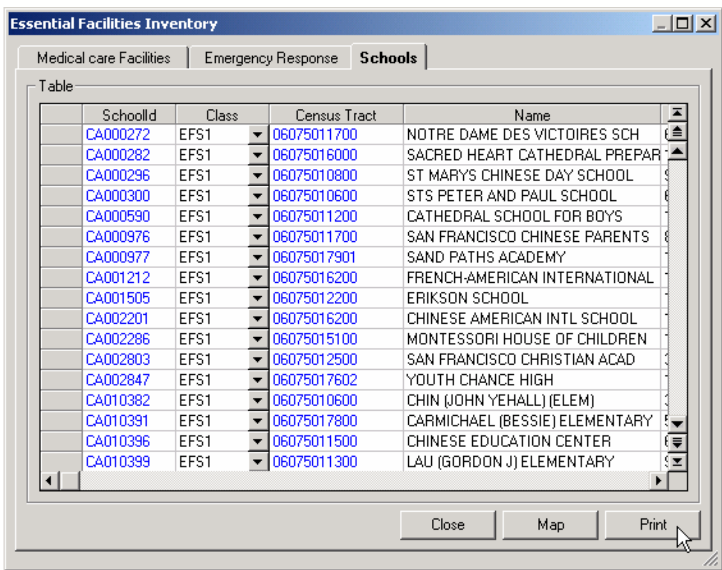


Figure 7.1 Print database.

7.3 Modifying Occupancy to Model Building Type Relationships

The method for creating and editing relationships between occupancy and building types is new with **HAZUS**. Modifications to these relationships are easily traced for comparative analyses.

On the main menu select **Inventory|General Building Stock|Occupancy Mapping**. The initial window opens with a table including the default occupancy mapping scheme for your region, as in Figure 7.2 Occupancy mapping schemes list.. The default scheme text is in blue, indicating that it cannot be edited. You will also see the total number of census tracts that have the mapping scheme assigned (default = all tracts). You can view the default scheme, create or import a new scheme, and print the list of occupancy mapping schemes that you have to use for the study region. Each scheme on the list is available to assign individual census tracts an occupancy map that accurately represents the area (vs. the default assignment). A mapping scheme may be deleted, but only when it is not assigned to a census tract.

Clicking the right mouse button when an occupancy mapping scheme is highlighted on the list will allow you to create a new scheme from a duplicate of the one you have selected. Choose the option **New** from the options menu and type in a new scheme name and description. Describe the new occupancy mapping scheme to explain variations in building types, age and height of buildings, originator of scheme, etc.

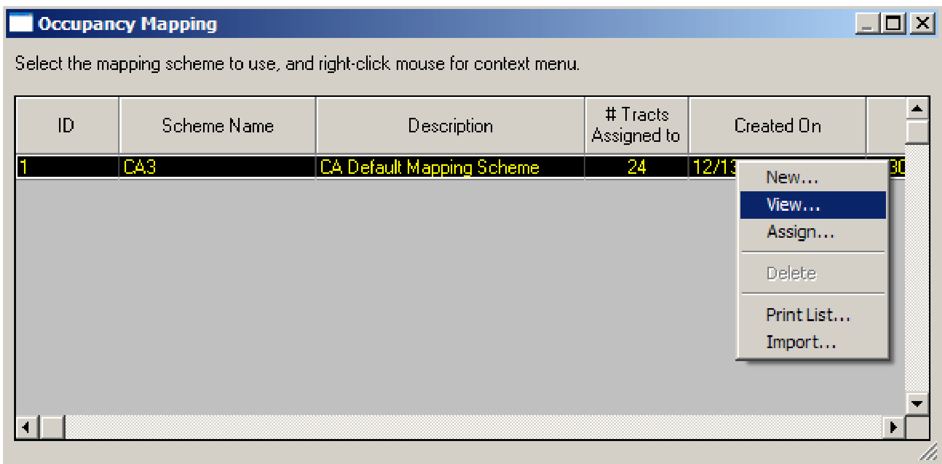


Figure 7.2 Occupancy mapping schemes list.

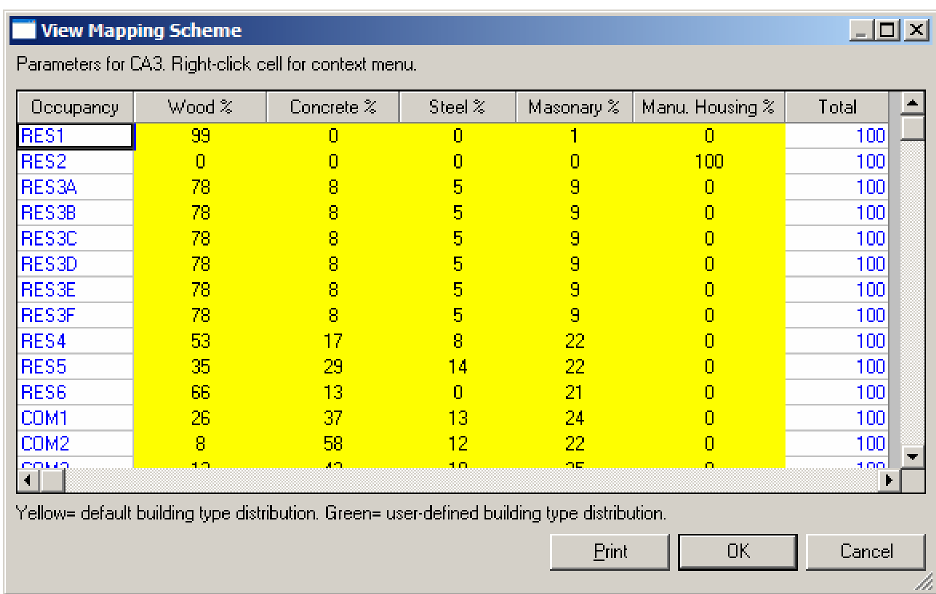


Figure 7.3 View of default Occupancy Mapping.

Error! Reference source not found. is the view of default values by general building type used to describe each occupancy type (ex. RES1, COM1). The makeup of each occupancy type can be changed to reflect the actual conditions for any single, or multiple census tracts. Each row of the spreadsheet represents an occupancy class and each column represents a model building type. For this example, retail trade stores (COM1) consists of 26% Wood, 37% Concrete, 13% Steel, 24% Masonry, 0% Manufactured Housing. The sum of the model building type percentages for each occupancy must equal 100, and the sum value is found in the last column of the spreadsheet, entitled "Total".

Occupancy mapping in **HAZUS** does not isolate age of the building as a variable; instead, the overall design level (High, Moderate, Low, and Pre-code) is considered when assigning a mapping scheme. Building height is accommodated in the building type sub-category. For example, a low rise reinforced masonry building (RM1L) may be used to map buildings used for commercial retail (COM1) or residential multi-family dwelling (RES4).

The composition of building types associated with each occupancy can be further refined by editing the characteristics of each general building type. Right-click on the spreadsheet cell corresponding to the occupancy/building type you wish to refine. Behind each percent value of a general building type is a distribution matrix that describes the quantity and quality of the buildings in that general building type category. When you edit the composition of buildings that make up each type, the spreadsheet cell will turn from yellow (default) to green (see Figure 7.4), signifying that the general building type has been customized.

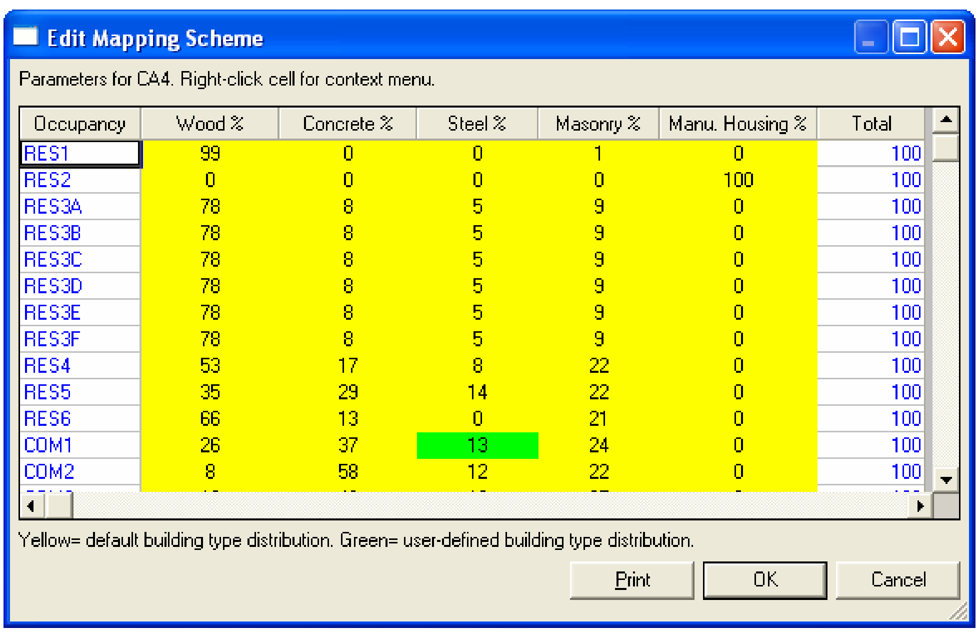


Figure 7.4 Composition of steel buildings occupied by retail commerce has changed.

For example, an old commercial center was torn down and half of it replaced by a new shopping mall in Census Tract 37019020501. Fifty percent of all the retail buildings in this one tract have changed the occupancy map for the census tract area. The new buildings were constructed to a high Seismic Design Level and superior to the existing Building Code, as shown in Figure 7.5. An occupancy map was created to reflect this change in steel buildings and the new scheme was assigned to the appropriate tract, as in Figure 7.6and Figure 7.7.

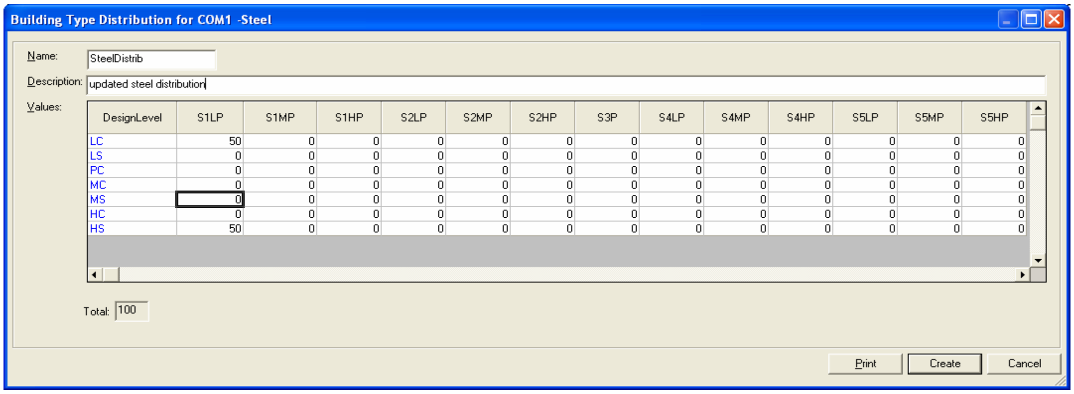


Figure 7.5 Fifty percent of the steel buildings are now superior (S) in building quality and high (H) in design level.

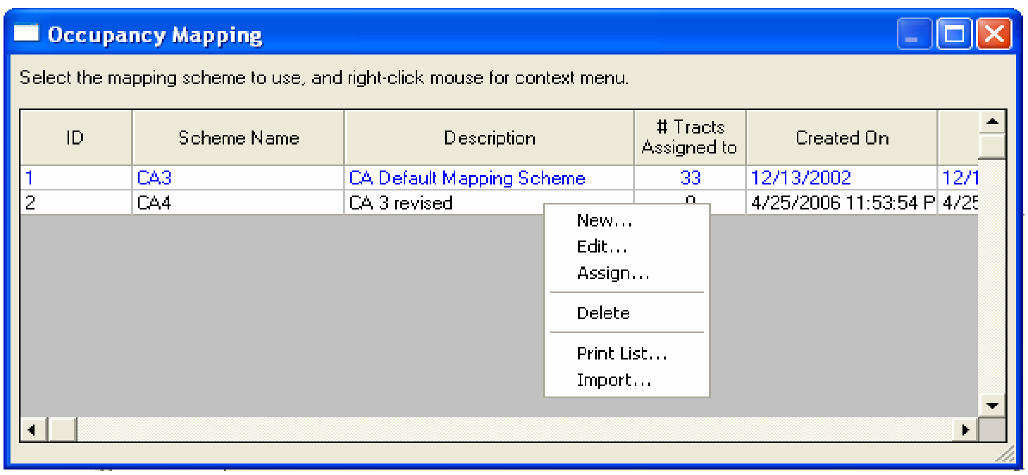


Figure 7.6 Select the new occupancy map to assign to a census tract.

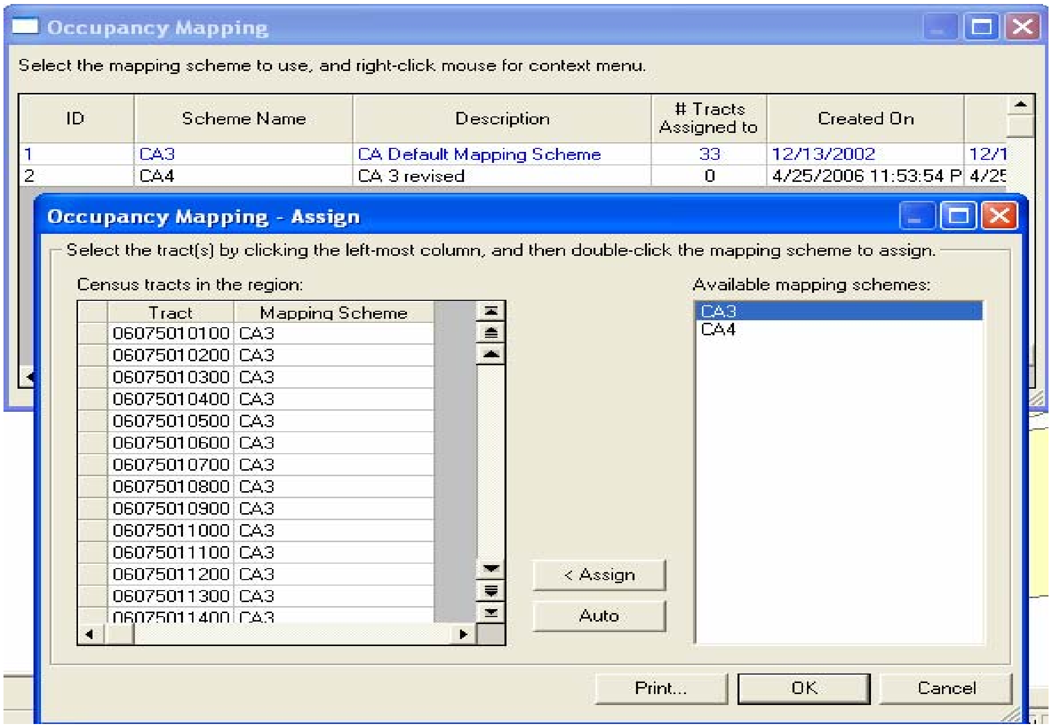


Figure 7.7 New occupancy mapping scheme assigned to a census tract.

7.3.1 Design Level

The design level designation is tied to the vulnerability to damage of a structure, and is reflected in the damage functions (fragility curves). Fragility curves are discussed in Chapter 9 of this manual and in the *Technical Manual*. **HAZUS** gives you the option to define a mix of design levels for each model building type. A mix of design levels can occur when structures are built at different times and are designed under different codes. The damage functions are based on current NEHRP provisions (FEMA, 1991a) and are intended to represent current code provisions. Damage functions are developed for each of three seismic design regions, defined in terms of the 1994 NEHRP Provisions map areas: High Seismic Design (Map Area 7), Moderate Seismic Design (Map Areas 5 and 6), and Low Seismic Design (Map Areas 1 to 4).

In those regions that have not enforced seismic design codes or have a number of buildings that do not meet current standards, the damage functions may under-predict damage. In contrast, the damage functions may over-predict damage for buildings that are designed/constructed for performance beyond code requirements. The latter case is not expected to include a large population of buildings and is not expected to affect regional damage/loss estimation.

The year when seismic provisions were included in building codes varies by region. The user should consult a local structural engineer or the local building department to determine what year seismic design provisions was enforced. Section 5.7 of the *Technical Manual* and FEMA publication 154 both provide some general guidelines for different regions of the United States.

7.3.2 Modifying the Mapping Scheme to Reflect Different Design Levels

Users may tailor the damage functions to their study area of interest by determining the appropriate fraction of each building type that gemerally conforms to current code provisions (ex. High in California, Moderate and Low in Florida), and the fraction that is substandard by a significant degree. Buildings that are considered significantly substandard would be assigned a lower seismic design group.

For instance, certain types of older buildings in Map Area 7 should be evaluated using damage functions for Map Areas 5 & 6. Such buildings would include concrete moment frames (Building Type C1) on the west coast built prior to the mid-1970's. Buildings over 60 years old were likely designed only for wind. At least a portion of these older buildings may best be evaluated using the damage functions developed for Map Areas 1-4. To modify defaults, users must be knowledgeable about the type and history of construction in the study region of interest and apply engineering judgment in assigning the fraction of each building type to a seismic design group.

7.4 Assigning Different Mapping Schemes to Different Census Tracts

The user can create a series of occupancy mappings by modifying the default values and saving the different mapping schemes under different names. Different mapping schemes can then be assigned to different census tracts. The reason the user may wish to create different mapping schemes is that building practices may vary throughout the study region. For example, in an older area 30% of the retail buildings (COM1) may be low rise unreinforced masonry (URML), while in more recently developed areas, only 5% of COM1 may be of model building type URML.

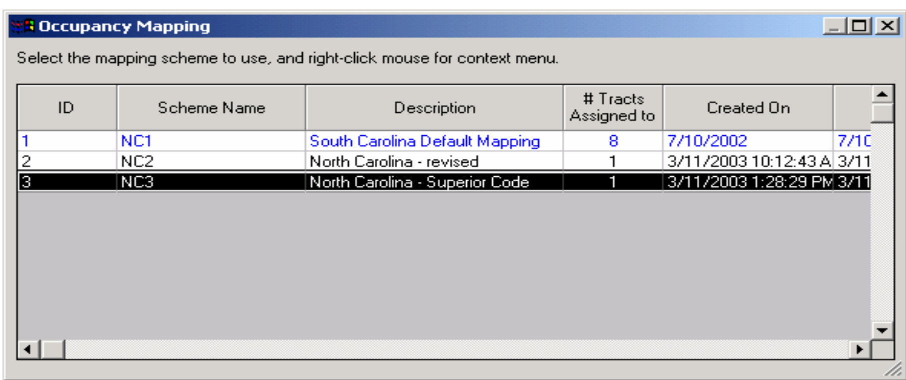


Figure 7.8 Tracking assignments of each occupancy mapping scheme.

7.5 User Specified Building Types

By default **HAZUS** supports thirty six specific building types as shown in Table C1 of Appendix C that could be grouped into five general building types Wood, Steel, Concrete, Masonry and Manufactured Homes. All the default mapping schemes, damage functions, debris parameters, casualty parameters available in **HAZUS** default data are based on these thirty six specific building types. What if a user has a building type not modeled by any of these thirty six building types? For example the user has an 8 storey

Reinforced Masonry Bearing Wall with Metal Deck building. By default **HAZUS** could model this building as a mid rise building only.

The User Specified Building Types is a new feature added to **HAZUS-MH since MR1** to allow the user to add a new specific building type that is not currently modeled by **HAZUS** methodology. Considering the above example, now you can model it as a high rise building by creating a new building type that represents a Reinforced Masonry Bearing Wall with Metal Deck High Rise.

On the main menu select **Inventory|General Building Stock|Define New Building Type**. The welcome screen of the Create New Building Type Wizard gets launched (Figure 7.9 Welcome Screen). Click on the Next button to proceed.

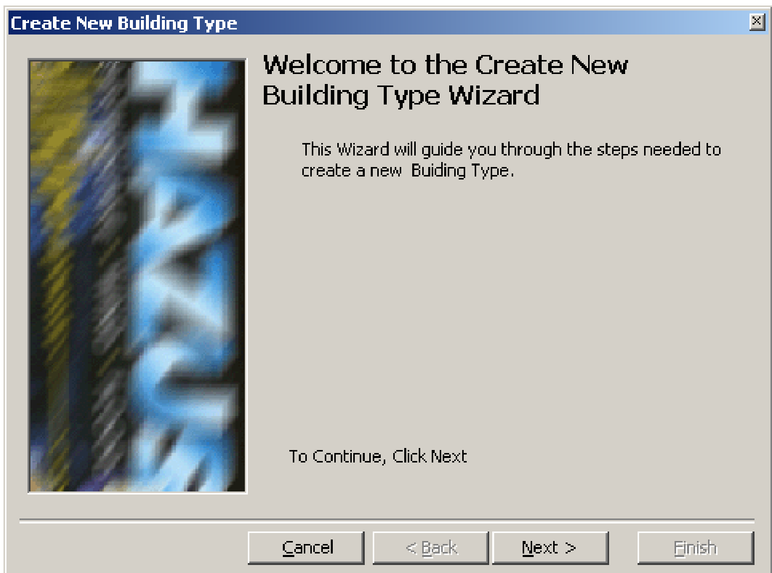


Figure 7.9 Welcome Screen

The Figure 7.10 Building Type Name/Description shows the first input screen of the Create New Building Type Wizard. Enter the name of the new building type, maximum 4 characters in length. Provide a detailed description of the building type in the Description edit box. This name must be unique across all the specific building types. In case the name you provide is not unique, the dialog will give you message. You must specify the general building type under which this new specific building type is to be modeled. This could be one of the five general building types namely Wood, Steel, Concrete, Masonry and Manufactured Homes. Next you should identify an existing Specific Building Type that most closely models the behavior of this new building type. This closest building type could be the one that you added earlier, i.e., it's not necessary that this closest building type should be one of the default building types. This information is used by **HAZUS** to provide initial values for damage functions, debris parameters and casualty parameters.

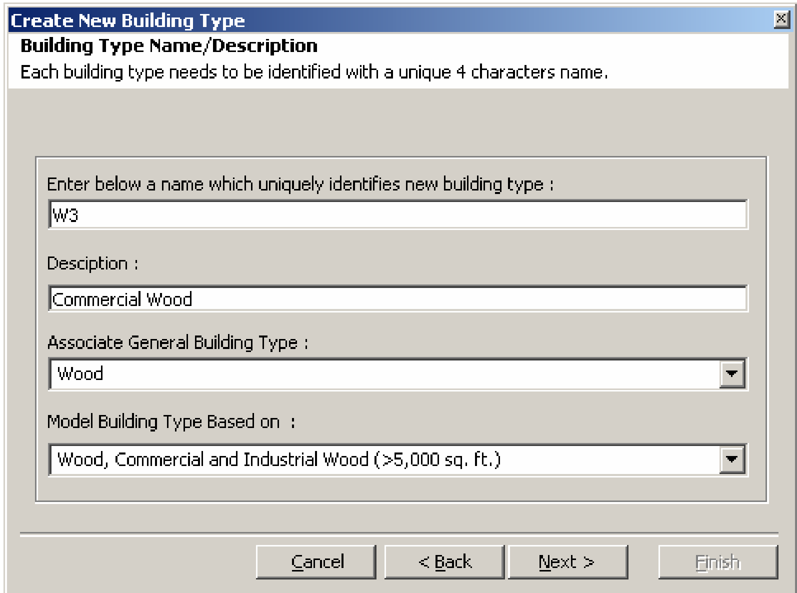


Figure 7.10 Building Type Name/Description

Click on the **Next** button to launch the **Building Damage Functions** dialog (Figure 7.11 Building Damage Functions). For every building type **HAZUS** needs a set of damage functions in terms of capacity curves that model the building strength, structural fragility curves that model the structural behavior of the building when subject to ground shaking, non-structural fragility curves that model the behavior of the non-structural components of the building when subject to ground shaking. The four items in the combo box correspond to these damage functions. Select an item and review/modify the default values provided by **HAZUS**. These default values a based on the closest building type selected in Figure 7.10 Building Type Name/Description. For details about Capacity and Fragility curves refer to section 9.3 of Chapter 9 in this manual.

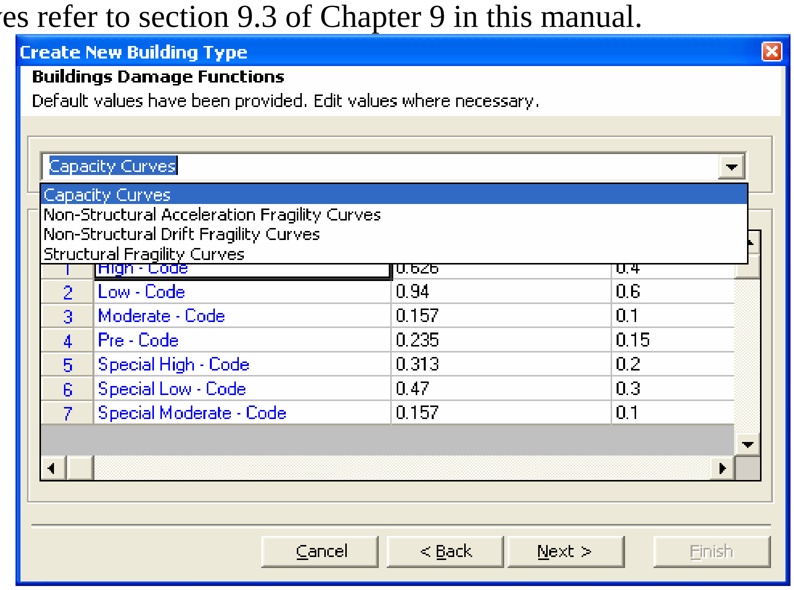


Figure 7.11 Building Damage Functions

Clicking the **Next** button will launch the **Debris** parameters dialog (Figure 7.12 Debris Parameters). You will see the default weight in tons of structural and non-structural elements per square foot of floor area and the amount of debris generated for each structural and non-structural damage state in terms of percent of weight of elements based on the existing building type selected for modeling this new building type in Figure 7.10 Building Type Name/Description. For details about these parameters refer to section 9.4.4 of Chapter 9. Review/Modify the necessary values and click on the **Next** button.

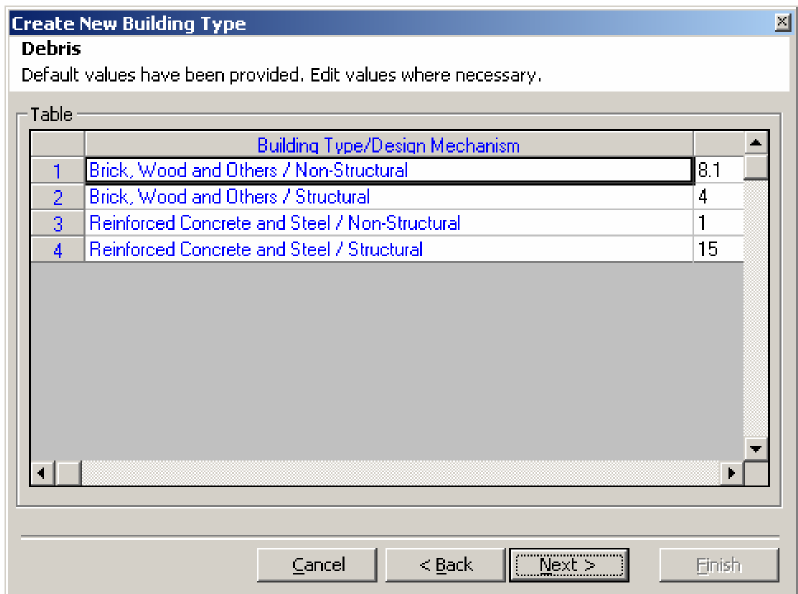


Figure 7.12 Debris Parameters

The **Casualty Parameters** dialog (Figure 7.13 Casualty Parameters) provides you the opportunity to tune the default Casualty Rates and Building Collapse rates provided by **HAZUS**. The Casualty Rates have to be specified for various damage states (refer to section 9.3 in Chapter 9 for details about damage states) for Inside the structure (Indoor) and outside the structure (Outdoor). Review/modify the necessary values. For details about Casualty module refer to section 9.5.1 of Chapter 9.

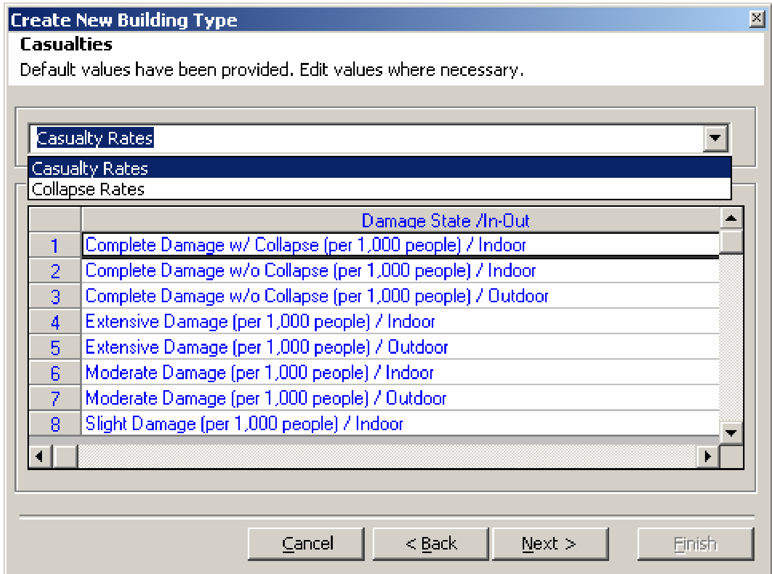


Figure 7.13 Casualty Parameters

Click next to view the Create New Building Type Wizard’s completion page. This shows the name, description and General Building Type for the new building type being created. If you are satisfied with these then click finish.

Figure 7.14 Completion Dialog

This may take a couple of minutes before the **HAZUS** menu will be available again. Now the new building type has been created and has been added to all the default and user create Occupancy Mapping schemes. Open the Occupancy Mapping dialog from **Inventory|General Building Stock|Occupancy Mapping** and modify the building type distribution to reflect the buildings in specific occupancies and this newly added building type. For details about how to modify a building type distribution refer to the section 7.3 above.

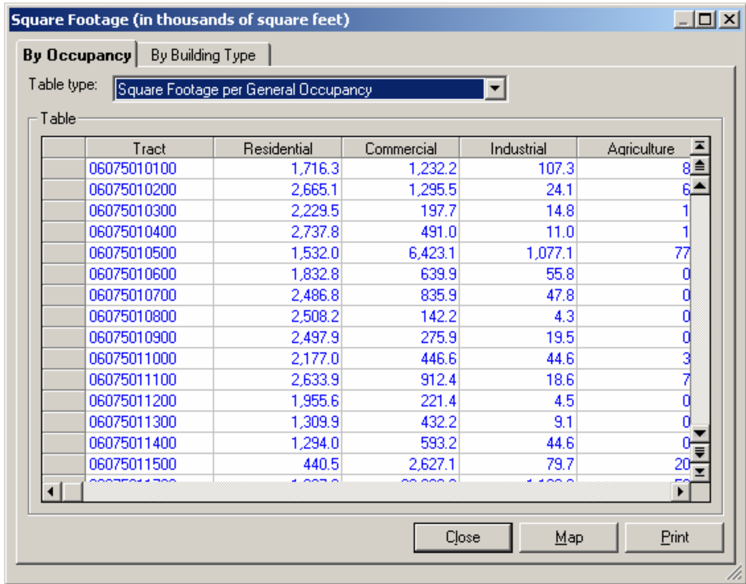
NOTE: It is very important to update the Occupancy Mapping Schemes' Building Type distribution before this new building type could be used by the model.

7.6 Display and Modification of General Building Stock

General Building Stock values are aggregated at the census tract level for estimating earthquake losses. The categorical set of values that comprise General Building Stock can each be displayed and modified: square footage, building count, dollar exposure, and foundation type. Occupancy mapping has been covered in the previous section. The following categories are found under the **HAZUS** menu **Inventory|General Building Stock**.

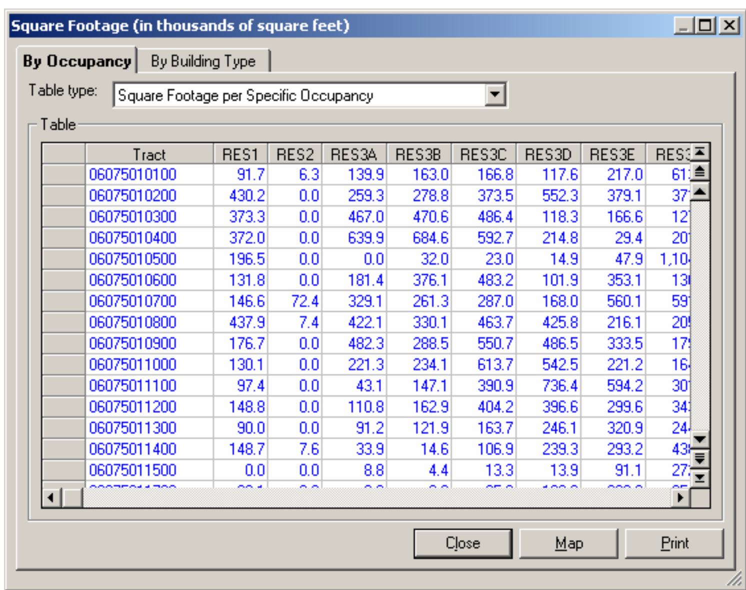
7.6.1 Display and Modification of Square Footage

You have the option to modify the distribution and total square footage of building structures by specific occupancy class. The default values are based on the 2000 Census and 2006 Dun & Bradstreet data; therefore, may not represent the most recent construction in your study region. Figure 7.15 Square footage by general occupancy class
(values in 1,000 sqft). displays total square footage in each census tract and by general occupancy. Figure 7.16 Square footage of buildings by specific occupancy class (values in 1,000 sqft). displays each census tract by specific occupancy. There are a total of 33 occupancy classes under the 7 general occupancy headings (ex. Residential, Commercial, Education, Industrial). This window is accessed from the **Inventory|General Building Stock| Square Footage** menu.



Tract	Residential	Commercial	Industrial	Agriculture
06075010100	1,716.3	1,232.2	107.3	8
06075010200	2,665.1	1,295.5	24.1	6
06075010300	2,229.5	197.7	14.8	1
06075010400	2,737.8	491.0	11.0	1
06075010500	1,532.0	6,423.1	1,077.1	77
06075010600	1,832.8	639.9	55.8	0
06075010700	2,486.8	835.9	47.8	0
06075010800	2,508.2	142.2	4.3	0
06075010900	2,497.9	275.9	19.5	0
06075011000	2,177.0	446.6	44.6	3
06075011100	2,633.9	912.4	18.6	7
06075011200	1,955.6	221.4	4.5	0
06075011300	1,309.9	432.2	9.1	0
06075011400	1,294.0	593.2	44.6	0
06075011500	440.5	2,627.1	79.7	20

Figure 7.15 Square footage by general occupancy class (values in 1,000 sqft).



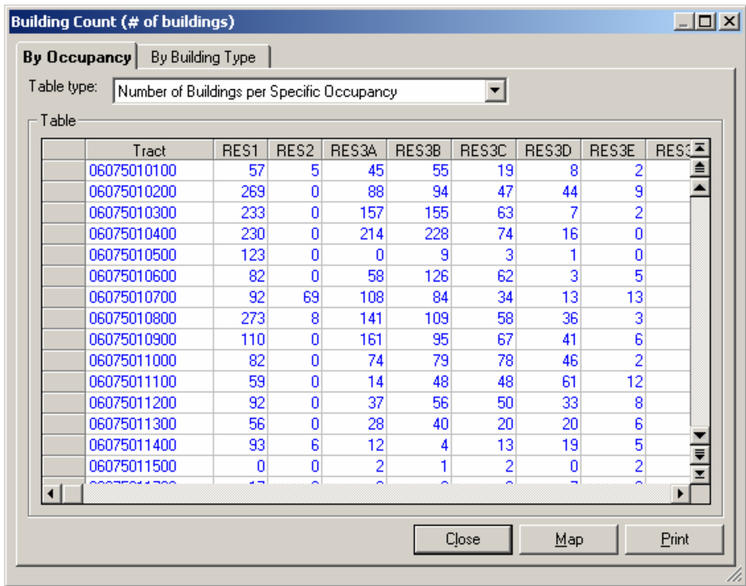
Tract	RES1	RES2	RES3A	RES3B	RES3C	RES3D	RES3E	RES3
06075010100	91.7	6.3	139.9	163.0	166.8	117.6	217.0	61
06075010200	430.2	0.0	259.3	278.8	373.5	552.3	379.1	37
06075010300	373.3	0.0	467.0	470.6	486.4	118.3	166.6	12
06075010400	372.0	0.0	639.9	684.6	592.7	214.8	29.4	20
06075010500	196.5	0.0	0.0	32.0	23.0	14.9	47.9	1,10
06075010600	131.8	0.0	181.4	376.1	483.2	101.9	353.1	13
06075010700	146.6	72.4	329.1	261.3	287.0	168.0	560.1	59
06075010800	437.9	7.4	422.1	330.1	463.7	425.8	216.1	20
06075010900	176.7	0.0	482.3	288.5	550.7	486.5	333.5	17
06075011000	130.1	0.0	221.3	234.1	613.7	542.5	221.2	16
06075011100	97.4	0.0	43.1	147.1	390.9	736.4	594.2	30
06075011200	148.8	0.0	110.8	162.9	404.2	396.6	299.6	34
06075011300	90.0	0.0	91.2	121.9	163.7	246.1	320.9	24
06075011400	148.7	7.6	33.9	14.6	106.9	239.3	293.2	43
06075011500	0.0	0.0	8.8	4.4	13.3	13.9	91.1	27

Figure 7.16 Square footage of buildings by specific occupancy class (values in 1,000 sqft).

Using the mouse, right-click on the **By Occupancy** table you wish to change. Select **Start Editing** from the options menu. Click in the spreadsheet cell to change each value. When you are done modifying the square footage value(s), right-click and select **Stop Editing**. You will be asked if you want to save your edits. The total square footage of the specific and general occupancy of each affected census tract will be automatically updated. Likewise, the corresponding square footage values by building type will change according to the occupancy mapping scheme you assigned.

7.6.2 Display and Modification of Building Count

Display and modification of building counts is done the same way described in Section 7.6.1. Only the values on the **By Occupancy|Number of buildings by specific occupancy** table may be changed (see Figure 7.17). The **By Building Type** table will reflect your edits according to your occupancy mapping scheme design. Building count values are expressed in absolute numbers for each census tract. This window is accessed from the **Inventory|General Building Stock| Building Count** menu.



Tract	RES1	RES2	RES3A	RES3B	RES3C	RES3D	RES3E
06075010100	57	5	45	55	19	8	2
06075010200	269	0	88	94	47	44	9
06075010300	233	0	157	155	63	7	2
06075010400	230	0	214	228	74	16	0
06075010500	123	0	0	9	3	1	0
06075010600	82	0	58	126	62	3	5
06075010700	92	69	108	84	34	13	13
06075010800	273	8	141	109	58	36	3
06075010900	110	0	161	95	67	41	6
06075011000	82	0	74	79	78	46	2
06075011100	59	0	14	48	48	61	12
06075011200	92	0	37	56	50	33	8
06075011300	56	0	28	40	20	20	6
06075011400	93	6	12	4	13	19	5
06075011500	0	0	2	1	2	0	2

Figure 7.17 Display and editing of building counts.

7.6.3 Display and Modification of Dollar Exposure

Risk exposure in dollars is treated separately from building counts and square footage. Modification to dollar values does not affect other General Building Stock categories. The dollar amounts of any specific occupancy type can be adjusted to better represent actual costs in the study region, and the totals will be updated.

Access the risk exposure tables using the **Inventory|General Building Stock|Dollar Exposure** menu. Only the values on the **Building Exposure** and **Content Exposure** tables under the **Exposure By Specific Occupancy** tab may be changed (see Figure 7.18). All other exposure values for occupancy and building type will be updated automatically when you right-click the mouse on the table to **Stop Editing**. Dollar values are expressed in units of $1000 for each census tract.

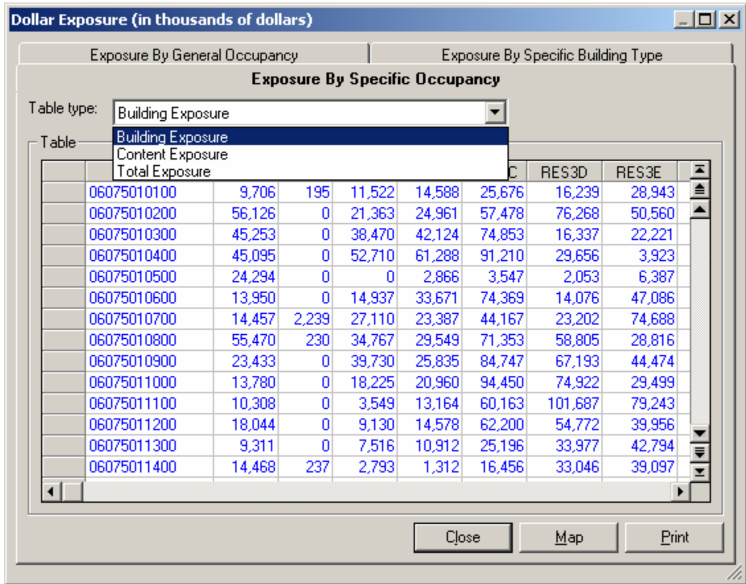


Figure 7.18 Building and content exposure values can be modified by specific occupancy class.

7.6.4 Mapping a Database

All databases can be mapped using the **Map** button at the bottom of the window. Each inventory has a default symbology, which can be modified using the ArcMap data layer **Properties** menu. The drawing order of each data layer is managed in the project file display list (Table of Contents). Site-specific databases, such as emergency facilities and lifeline components, will appear as point symbols on the map. Census data, soil types, and general building stock inventory are displayed as thematic maps. In thematic maps, shading or colors can be used to display attributes of a particular region. Variations in population density are displayed in Figure 7.19.

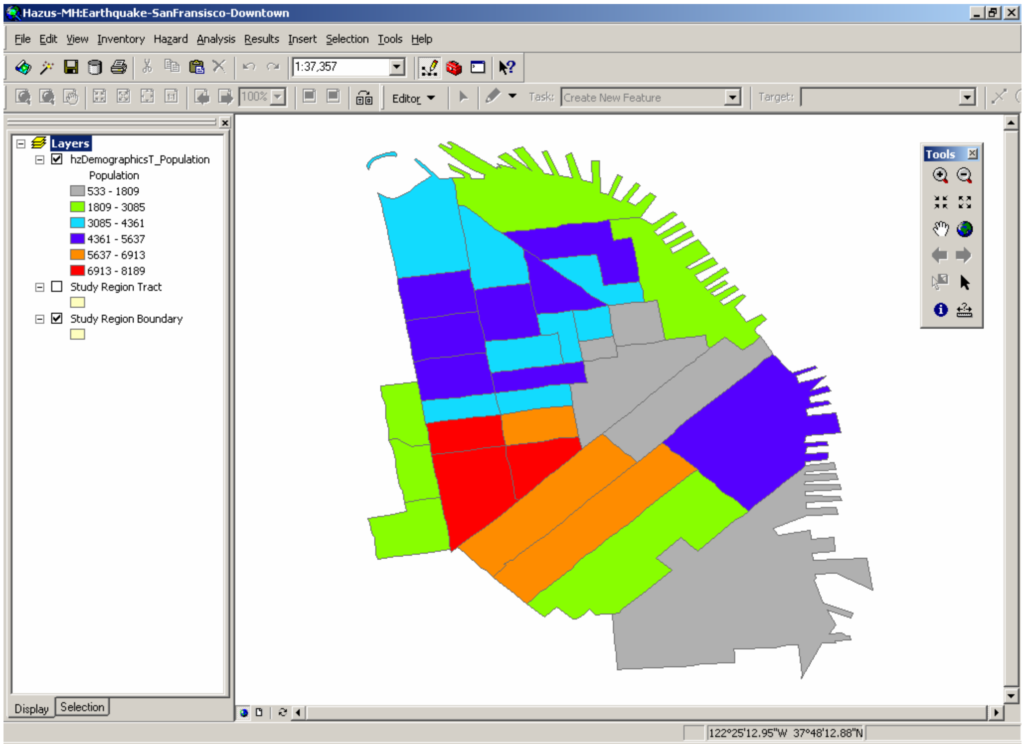


Figure 7.19 Default thematic map of population as displayed by HAZUS

In order to map the population information shown in Figure 7.19, click on the column header *Population* to highlight the entire column of the database. When you click on the **Map** button at the bottom of a database window (see Figure 7.20), a thematic map will be displayed using a default legend for the ranges and colors of data. Customize the look of a map display to meet your own needs by clicking the right mouse button on the data layer of interest to access the ArcMap **Properties|Symbology** menu.

Apply ArcMap symbology options to re-classify the value ranges, or set new colors and patterns to each attribute class (i.e. population). Labels can be modified using the data layer **Properties|Labels** menu. Save your legend modifications by clicking the right mouse button over the data layer of interest and selecting **Save As Layer File**. The layer can be loaded from the ArcMap **Properties|Symbology** menu, which has an **Import** option.

For more details on modifying legends and general instructions in using ArcMap, see ESRI's software manual. The functions detailed in this manual are primarily for executing loss estimation analysis. The **HAZUS** software operator is expected to have some familiarity with ArcGIS, and be able to access the program help options as needed.

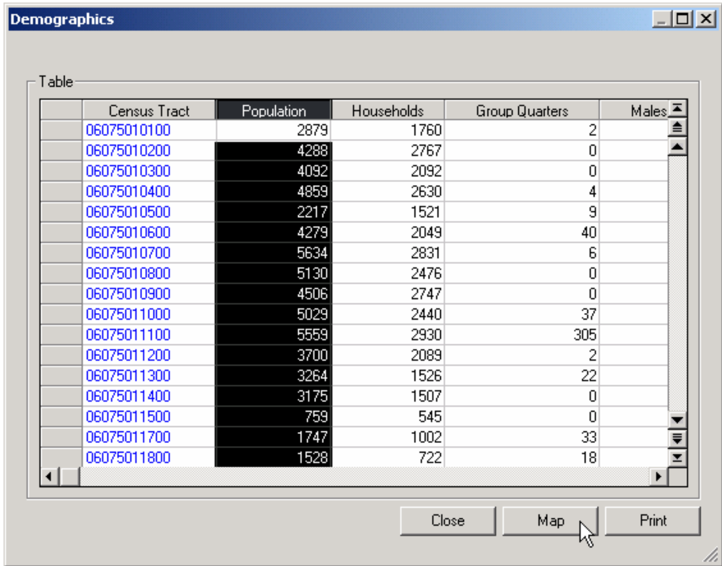


Figure 7.20 Highlighting the population column of the population inventory.

7.6.4.1 Creating a Layout Window and Printing Maps

Create a map layout to format your **HAZUS** data for printing. Change the window view from **Data** to **Layout** by selecting the option button at the lower left corner of the map display area. The default **HAZUS** map layout will appear with your data. Re-scale and arrange the pieces of the layout (i.e. legend, title, date, author of map) as you find most useful to the viewer. Save your work under the ArcMap **File|Save** menu, and print according to your printer specifications from the **File|Print** menu.

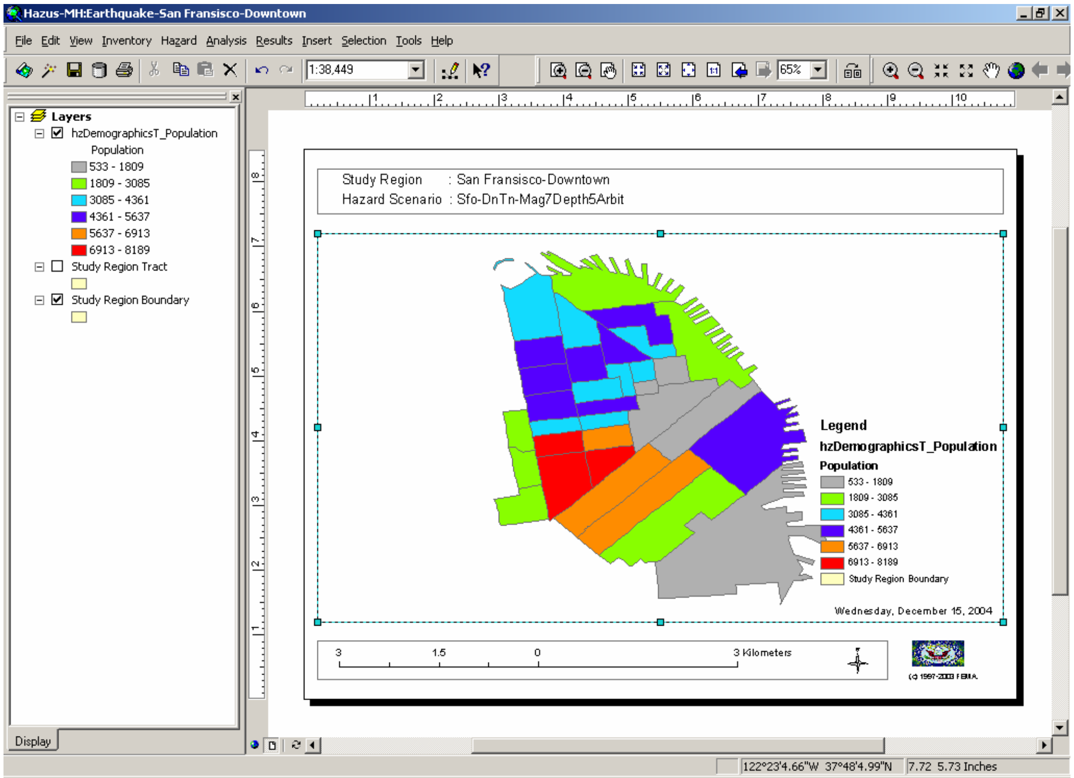


Figure 7.21 Layout window, used to modify a map for printing.

Chapter 8. Building-Data Import Tool (BIT)

The building-data import tool (**BIT**) is a utility that is designed to help you import large databases of property information and to process that data so as to be able to create occupancy to model building type relationships. It can read a variety of different types of database formats and configurations and will translate these into a standard format for use by **HAZUS**. The **BIT** includes a utility that allows you to run queries on databases so that you can identify certain types of properties (e.g. unreinforced masonry) or gather information about buildings with certain characteristics.
In HAZUS-MH MR3, the BIT utility is deprecated, and has been replaced by the CDMS tool.

8.1 Getting Your Data in the Right Format

Before you run **BIT** you need to ensure that your data is in a form that the program can process. For example, if you have purchased tax assessor's files on magnetic tape, you will have to have those tapes read and transferred to floppy disk or CD-ROM. You will need to convert your database to a Microsoft Acess (.mdb) format if it is in some other database format such as *.dbf, *.db, *.xls, etc. Another problem that can occur is that square foot building area is not reported as a single number but instead a sub-area is given for each floor or each portion of the building. In this case you will have to sum the individual sub-areas for each building and put the total building area in a single field. In the case of commercially available property data, you will need to extract the records from the database using software supplied by the vendor. Other problems you may encounter are appearance of properties more than once if they have multiple owners, or the reporting of multi-building complexes, and the use of two or three different occupancy definitions for a single property. All of these will require judgment on your part, and some of these problems will be very challenging.
BIT can only work with the following three types of files:

- Microsoft Access database (*.mdb)
- ASCII text file (*.asc). Any delimiter can be used (comma, tab, etc.)

If your database is not in one of these two formats, you will need to use an external database management program to convert your data into one of these formats.
The **BIT** can only import data from one county at a time. If your data file contains properties from multiple counties, you will need to use a database management program to sort the data by county and organize the data into separate files for each county.

8.2 Starting BIT

BIT can be launched in two ways: either from within **HAZUS**or stand-alone.
To launch **BIT** from within HAZUS, select the command **Inventory|General Building Stock|Building Import Tool (BIT).**
To launch **BIT** independent of **HAZUS**, select **Start|FEMA Risk Assessment System|BIT.** This location assumes that **BIT** was installed in the default group (**FEMA Risk Assessment System)**.

8.3 Specifying the Input File

After starting the **BIT**, you will be presented with the window shown in Figure 8.1. This window guides you through the five steps needed to develop the occupancy to model building type relationships for your region. The first step in the process is to specify the property data file you will be using. To start this step click on the **Specify Input File...** button.

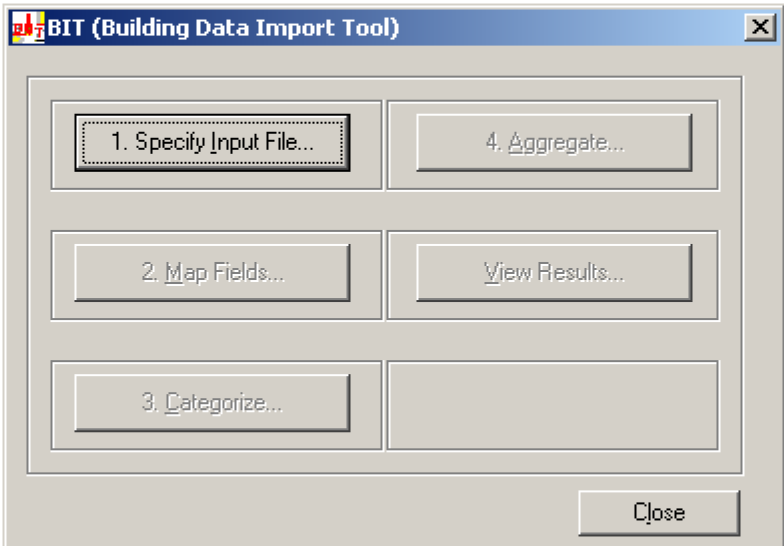


Figure 8.1 Building data import tool main menu

You will be asked to select an input file. You can choose from one of the four following options: ASCII text file (*.asc), Microsfot Access Table (*.mdb), configuration file (*.bcf). A configuration file is generated by the **BIT**, and is available only if you have started the import process previously, but did not complete all five steps. The *.bcf file allows you to continue an incomplete import activity without starting over from the beginning.

8.3.1 Importing an ASCII Delimited Database

After you click on the **Specify Input File...** button in Figure 8.1, you will be presented with the window shown in Figure 8.3. Suppose that the particular property data file that you want to import is an ASCII delimited file. A delimited file is one that uses a specific character to separate the fields of information. Delimited files come with a variety of different characters to separate the fields. The most common are the comma and the tab. However, the delimiter can be any character. An example of two records from an ASCII comma-delimited file is shown here:

```
”521-525 Main St”,”Anytown”,”94102-1102”,”121.00”,”Store
Building”,4195,”1”,2,”883263”,16,”79”,””,”880720”,”C”,”Concrete”,”Stucco
”,”Concrete”,”Steel”,”Flat”, ”Built-up”,””,”Average”,”$357”,”,”,”0284-
000”
```

```
"332 North St","Anytown","94102-2607","125.00","Apartment",16030,"6",24,
"341314",23,"72","72","830404","C","Concrete","Concrete","Concrete","Con
crete",
"Flat","Tar & Gravel","","Fair","$17",",",","0333-001"
```

Figure 8.2 Two records from a comma-delimtied text file

Each record shown in Figure 8.2 spans three lines and each field is separate by a comma. Quotes are used to indicate alphanumeric (text) data and entries without quotes are numbers. The **BIT** is capable of distinguishing these two types of inputs and it shouldn't cause you any problems when both types appear in the same record. It is important to understand that the **BIT** can recognize this file as ASCII delimited <u>only</u> if you specify the filename extension as .asc.

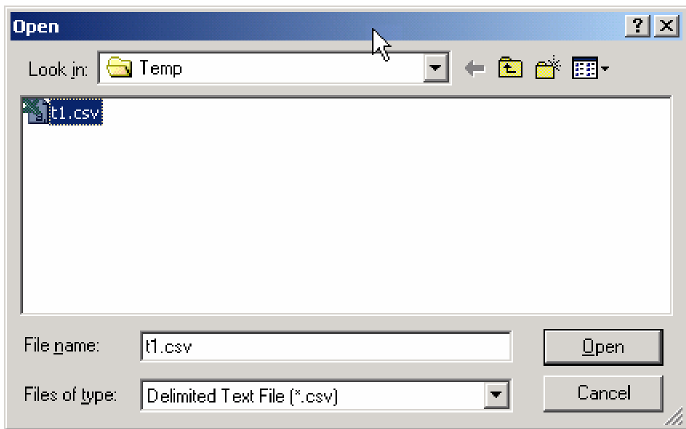


Figure 8.3 Specifying a *.csv input file in the building-data import (BIT) tool

After you have specified the file name in Figure 8.3, you will be asked to specify the type of delimiter that is being used as shown in Figure 8.4. If the delimiter is not a comma or a tab, click on **<u>O</u>ther** and then type the delimiter in the box to the right. The delimiter can be a single character such as a ' or a ? or a !. At the bottom of the Delimited ASCII Import window is a box entitled **Change default field <u>n</u>ames**. If you mark this box, you will be presented with the Field Names window shown in Figure 8.5.

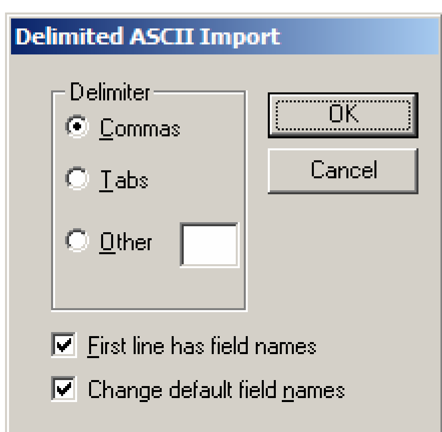


Figure 8.4 Specifying the delimiters for an ASCII delimited file

Generally, an ASCII delimited file does not contain embedded field names. Thus when the ASCII delimited file is read by **BIT** the fields will be called Field001, Field002 and so on. The supplier of the data file should have provided you with documentation that indicates what is contained in each field. The Field Names window in Figure 8.5 allows you to rename the fields in your database so that they are easier to keep track of (this window is skipped if the option "Change default filed names" is not checked). To make a change, double click on the field name so that it is highlighted, then type in the new name. When you have changed the desired fields (you do not have to name all fields), click the **OK** button to save the changes. Optionally, you could embed the names of the fileds at the first line in the input file and make use of by checking the option "First line has field names".

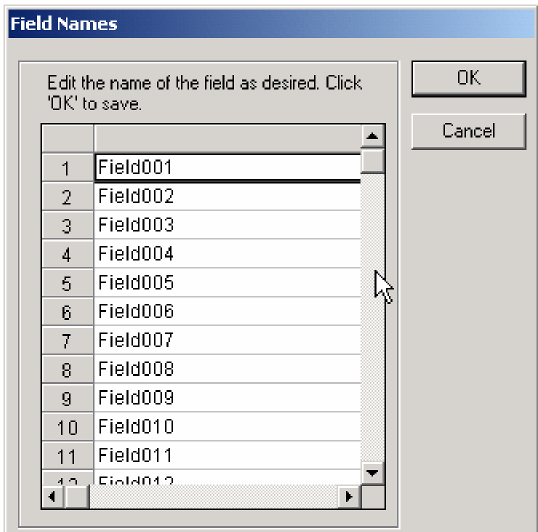


Figure 8.5 Changing the field names in an ASCII delimited file

Once that is specified, the second option is enabled.

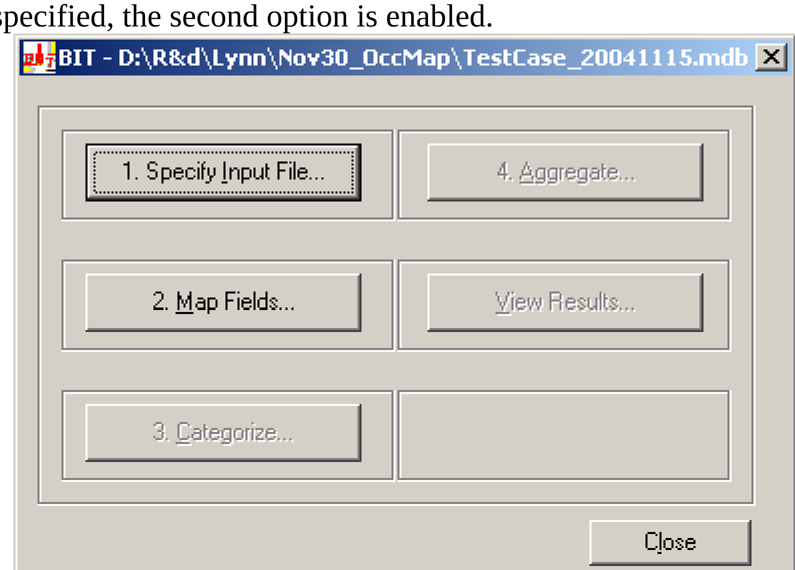


Figure 8.6 Task 2 "Mapping Fields" enabled.

8.3.2 Importing a *.mdb Database

A file that is in an *.mdb format does not require some of the steps that are required for an text file. Simply specify the database file name as shown in Figure 8.7. You will then be presented with a list of tables in the database. Select the desired table to import and click **OK**, and you will be ready for mapping fields (see Section 8.4).

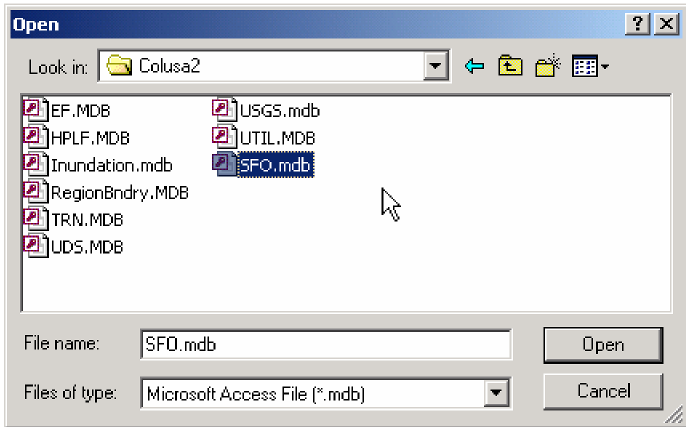


Figure 8.7 Specifying an *.mdb input file in the building-data import tool

8.4 Mapping Fields

After having specified the input file, you will need to map the fields in your database (the source) to the fields used in the **HAZUS**database (the target database). The steps for importing data and creating occupancy to model building type relationships must be completed in the numbered sequence. The labels for steps that are not yet available to you will appear in light gray. To start this step, click on the **Map Fields** button in the main **BIT** menu (see Figure 8.8).

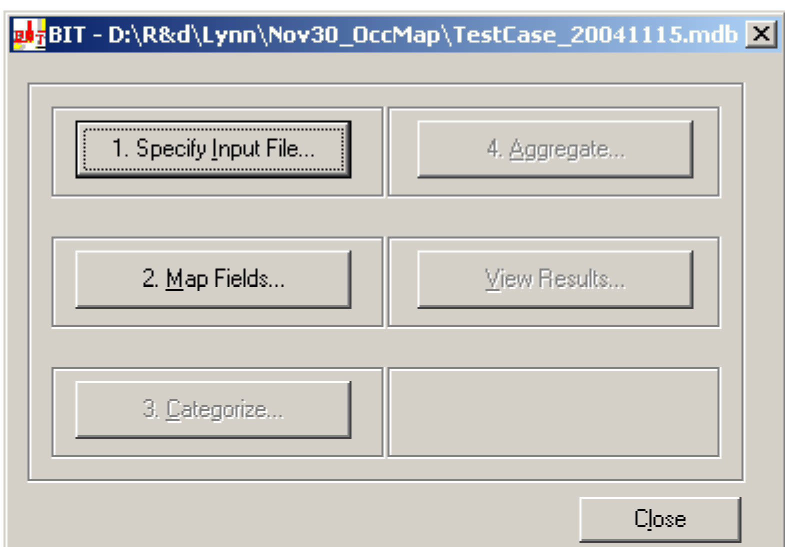


Figure 8.8 Starting the field mapping step from the BIT main menu

Since the **BIT** is used to develop occupancy to model building type relationships for your region, the most important information to capture is the occupancy, structural type, square footage and height of your buildings. However, the database you create can have as many fields as you want, allowing you to maintain many types of data. Using the mapping tool outlined in this section, you can be certain that all of the databases you maintain will be in a standard format.

The mapping window shown in Figure 8.9 is used to map the fields in your database (the source) to the fields used in **HAZUS** (the target database). The source-database fields do not have to be in the same order nor do they have to have the same names as the target-database fields. For example, in Figure 8.9 the occupancy types are in the field seventh field (“Field007”) in the source database whereas the field that contains this information in the target database is called “Occupancy”.

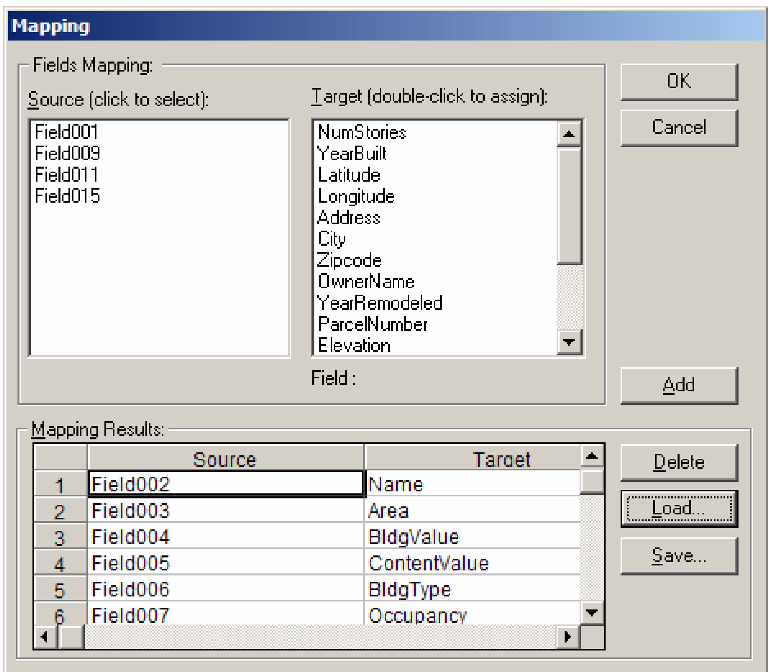


Figure 8.9 Defining a mapping scheme from the source database to the target database in the BIT

To define the desired mapping, simply click on a field name in the source database (e.g. Field004) and the corresponding field name in the target database (e.g. BldgValue) and then click on the **Add** button. After each time you perform this operation the mapping you have defined will appear in the **Mapping Results** box at the bottom of the window. At the same time, these fields will disappear from the **Fields Mapping** box at the top of the window. If you make a mistake, click the **Delete** button and the last mapping pair you have defined will be undone. When you have completed mapping all of the fields, click on the **OK** button, wait a moment, and your database will be reconfigured into the standardized format. At the end of this step a table with the same name as your original file is created in the syBIT database in SQL Server. Your original file will remain unchanged. NOTE: You do not have to map all of the fields from the source database;

however, any fields you do not map will not be imported into the target database. There are key fields that must be mapped without which you won't be able to proceed with the mapping. The **BIT** tool will prompt you with the key field (s) that you missed mapping once you try to click the OK button to move on to the next step. An example of this window is shown in Figure 8.10. The window also includes the list of the "must mapped" fields for the **BIT** tool. Table 8.1 list in detail the required fields and how they are by **BIT.**

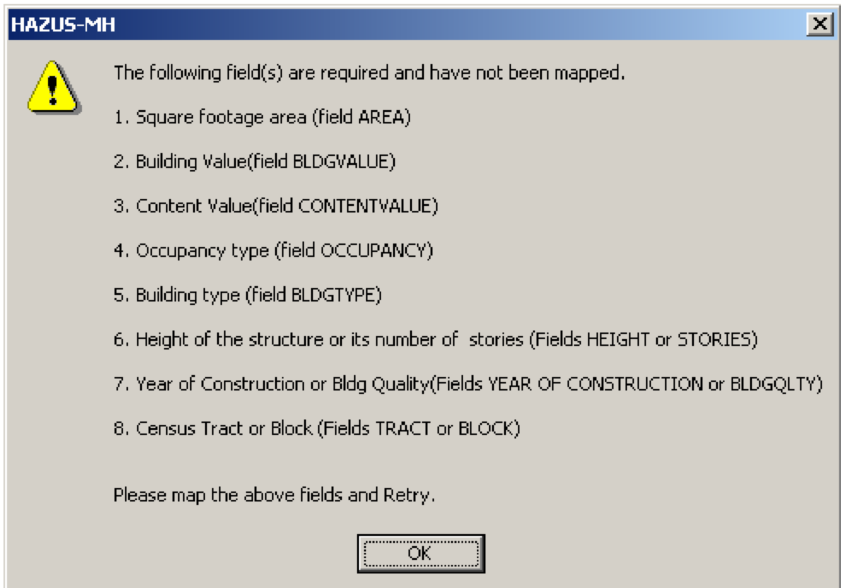


Figure 8.10 An example of a warning message in case you miss mapping key field(s)

It is possible you have several databases with the same format and you would like to save the mapping that you have just defined. Before you click the **OK** button, click the **Save** button in Figure 8.9. A save window will appear and you will need to enter a name for the saved mapping scheme. Retrieve the saved mapping scheme by clicking on the **Load** button in Figure 8.9.

	Field	Field Name in Target Table	Description
1	Area	BldgArea	Built area for building in sq. ft (BIT will adjust the # if not in sq.ft using the conversion factor supplied)
2	Building Value	BldgValue	Current bldg value. Desired unit is in K$ (BIT will adjust the # if not in K$ using the conversion factor supplied)
3	Content Value	ContentValue	Current content value. Desired unit is in K$ (BIT will adjust the # if not in K$ using the conversion factor supplied)
4	Building Type	BldgType	The 'Categorizing' process will translate this to HAZUS specific bldg type.
5	Occupancy Class	Occupancy	The 'Categorizing' process will translate this to HAZUS specific bldg type.
6	Height or # of stories	Height or NumStories	Height (in ft.) if given will converted to # stories to make use of the L, M, or High-rise classification
7	Age or Year of Construction or BldgQuality	BldgQuality	Age/Year of Construction get translated to bldg quality values (C, S, I)
8	Earthquake Design Level	DesignLevel	Optional. If not given, the default for the county will be used.
9	Tract or Block	Tract or Block	Tract is 11-char. Block is 15-char.

Table 8.1 List of BIT-MH required fields

8.5 Categorizing Data

The next step in creating standardized data formats is to convert the data to the classification systems of HAZUS. For example, your database may use the term "wood" for low-rise wood frame construction whereas this would be classified as a W1 model building type in **HAZUS**. Thus, records with structural type "wood" in the source database need to be converted to "W1" in the target database. To do this step, click on the **Categorize...** button shown in Figure 8.11. At the end of this step a new file will be created. It will have the same name as your original file and a new extension: .TG2.

This database is the same as the *.TG1 database except that all of the replacements you have requested have been made.

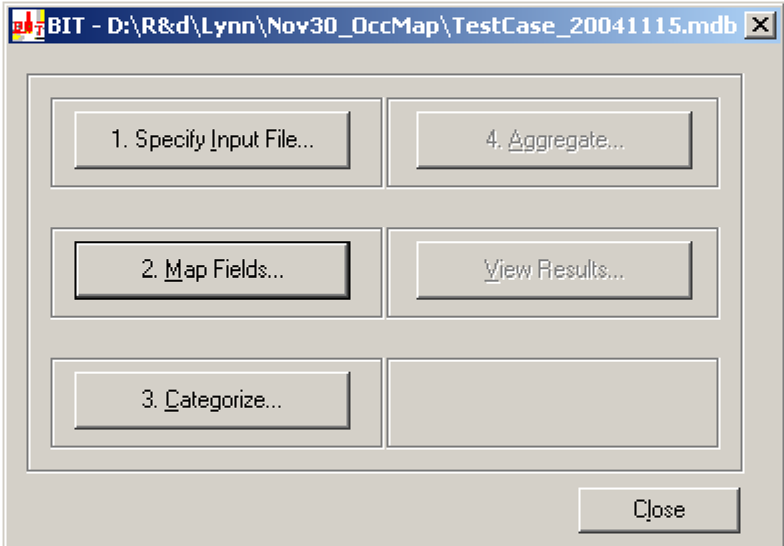


Figure 8.11 Starting the categorize function of the BIT

You have the option to select which fields of data you want to categorize (see Figure 8.12). It is likely that none of your data will be in the standardized format and you will want to select the 'Select All' option. To select the items, simply click on them. When you are finished, click the **OK** button.

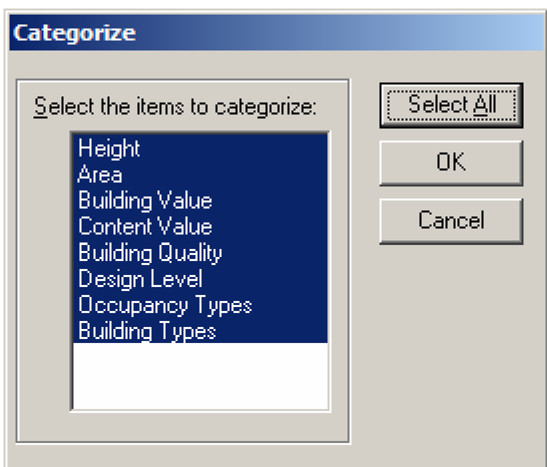


Figure 8.12 Selecting which fields you want to categorize

8.5.1 Categorizing Number of Stories Data

HAZUS groups of buildings into low, medium and high-rise structures. Thus ultimately, any building with one to three stories height will be classified as low rise. If your database uses numbers to specify the height of the building in feet, the **BIT** will automatically convert the height to low, medium or high-rise. If the building height that you have is in non-feet units, you can use the conversion factor[11] to convert the data to feet. If on the other hand the database that is being used has characters or words for number of stories, then you will need to define a mapping scheme to convert your data to the standardized format. The window in Figure 8.13 is used to indicate which of these situations apply to your data.

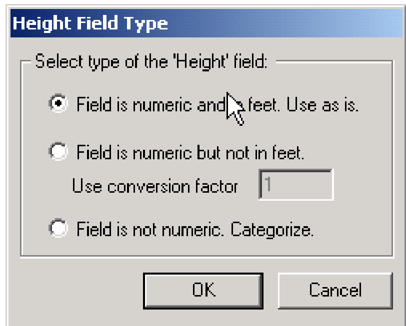


Figure 8.13 Indicating what type of building story data you have

If you click on **Field is non-numeric. Categorize**, then press **OK**, the window in Figure 8.14 is displayed allowing you to define a mapping from your database to the standardized format. As with other mapping windows, after you have defined each mapping, click on the **Add** button and the mapping will appear in the **Results** portion of the window. If you make a mistake, use the **Delete** button.

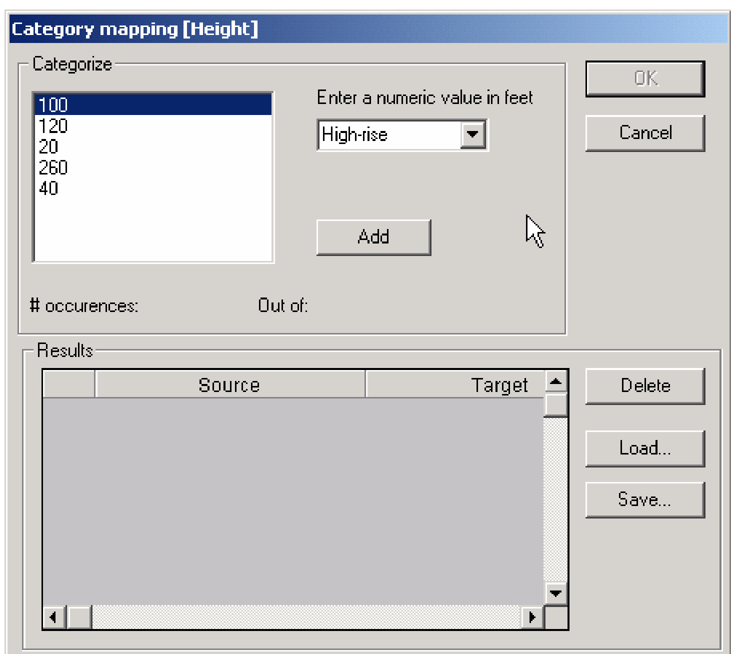


Figure 8.14 Categorizing number of stories data

[11] The conversion factor is used as a **multiplier,** in other words, it takes the original values in the input file, multiplies them by the conversion factor supplied and uses the result.

To save your data mapping scheme, click on the **Save...** button. Use the window shown in Figure 8.19 to name the mapping scheme. A scheme for mapping number of stories will have an .ssl extension, whereas a scheme for mapping building height will have an .hsl extension.

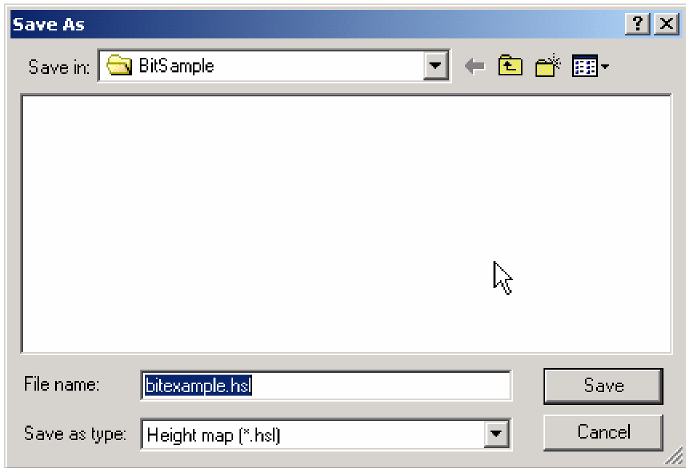


Figure 8.15 Saving number of stories categories

8.5.2 Categorizing Year Built Data

HAZUS lumps buildings into three age groups: pre-1950, 1950-1970 and post-1970. Occupancy to model building type relationships is developed for each of these three groupings. Year-built data is found in a variety of formats in assessor's files and other commercially available property files. It is most common to find the year built expressed in a two-digit format, such as 95, or in a four-digit format, such as 1995. However, it is possible that other formats could be used such as old, moderate and new. The **BIT** has the flexibility to read any of these formats by selecting the appropriate buttons in Figure 8.16. Perhaps most problematic is how to deal with a zero. A zero can mean that a structure was built in 1900, or in 2000. You may have to ask the supplier of the data how to interpret the occurrence of a zero in the data.

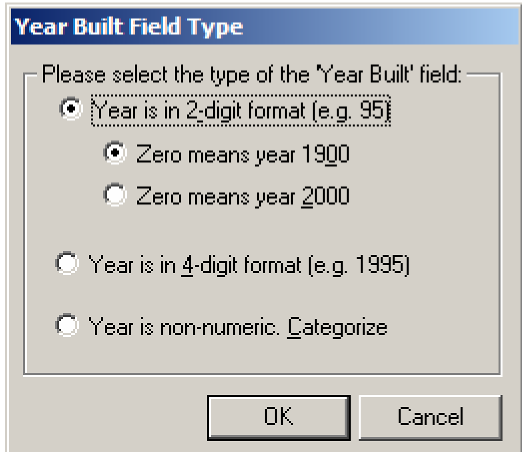


Figure 8.16 Categorizing year built data

8.5.3 Categorizing Occupancy Class Data

In this step you will be required to map the occupancies found in the source database to the standardized occupancies defined in **HAZUS**. All of the 33 specific occupancy classes found in Table A.3 are listed in the **Target** list box found in Figure 8.17. In addition to the specific occupancy classes, you will find five general occupancy classes (Residential, Commercial, Industrial, Government, and Education) and the class "Unknown". General occupancy classes are in all upper-case letters. Some property databases contain very limited information about occupancy; for example, labels such as residential, commercial, and industrial. In this case you will need to use the general occupancy classes for categorizing occupancy.

To define a mapping, click on an occupancy in the **Source** list box and then double click on the corresponding standardized occupancy in the **Target** list box. You can not map multiple occupancies at the same time in the Source list box that corresponds to a single standardized occupancy. This resulted in the four separate mappings found in the **Mapping Results** box. If you find you have made a mistake any time during this process, simply click on the incorrect mapping in the **Mapping Results** box and click on the **Delete** button. Redefine the correct mapping for that occupancy and continue. When you have completed the mapping for all categories in the source database, click the **OK** button.

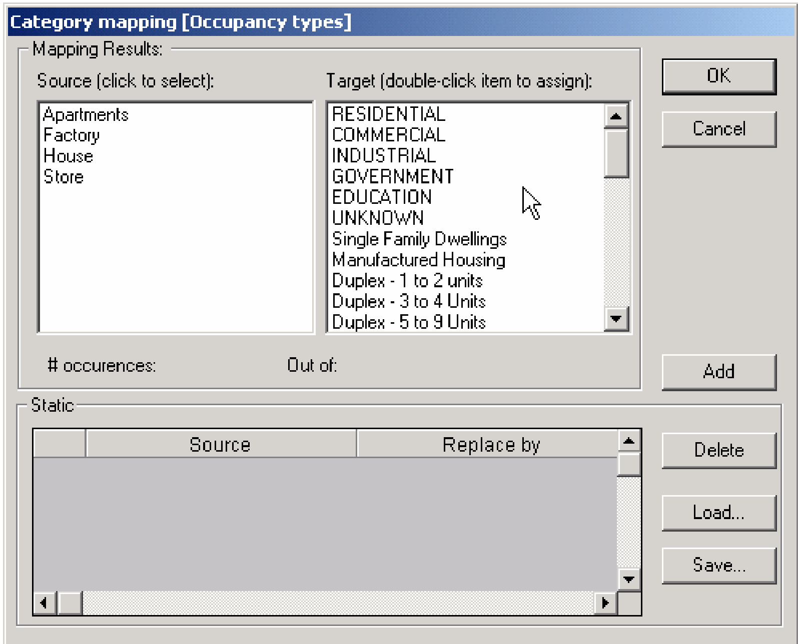


Figure 8.17 Categorizing occupancy class data

Categorizing occupancy class data can be somewhat tricky and can require judgment on your part. Some of the occupancy classes in the property file may not fit perfectly into **HAZUS** classifications. For example, you may find a class such as "Office & Residential" in your database that could be classified as either RES3 "Multi-Family Dwelling" or COM4 "Financial/Professional/Technical Services". You will have to use your judgment in deciding which standardized class best typifies this mixed occupancy. Another problem you may find is that source-database occupancy classes do not always provide a correct description of the property. For example, parking lot, residential lot or vacant lot would imply that these properties have no structures on them. However, in many cases in the sample database used here, there were buildings on these types of properties. You should not be surprised to find that certain occupancies such as universities, institutional housing and government services, to name a few may, be completely absent from your database. As noted in Section 5.1.2, property databases rarely provide detailed information on tax-exempt properties.

As with other mappings defined in the **BIT**, you have the option to save the occupancy class mapping for use on other files. To save the mapping, click on the **Save...** button before clicking **OK**. The occupancy mapping file will be saved with an .osl extension as shown in Figure 8.18. To use the mapping in the future, click on the **Load...** button in Figure 8.17.

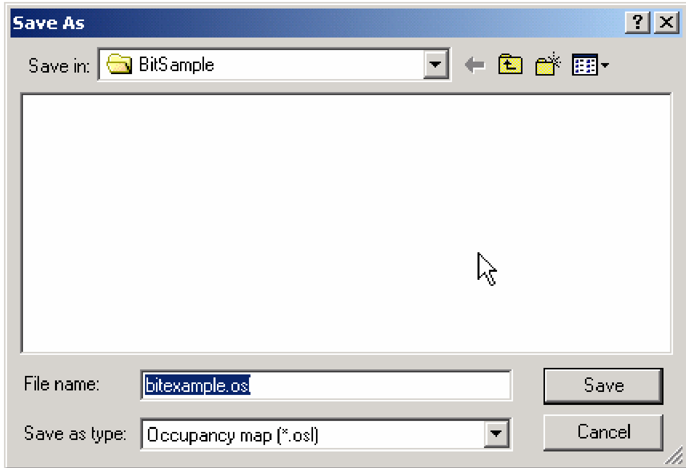


Figure 8.18 Saving an occupancy mapping scheme

8.5.4 Categorizing Building Type Data

In this step you will be required to map the structural types found in the source database to the model building types defined in **HAZUS** (See Appendix B, Table B.2). The 16 general building types found in Table B.2 are listed in the **Target** list box shown in Figure 8.19. In addition to the general model building types, you will find four basic building material types (Wood, Steel, Concrete, and Masonry) and the class "Unknown". Basic building material types are in all upper-case letters. Many property databases contain very limited information about the structural system used, and the categories used are often based on fire safety information. For example, in this sample database shown in Figure 8.19, category C contains brick, tilt-up and formed concrete construction. The user has chosen to map category C to masonry. Clearly, this will introduce uncertainty into the occupancy to model building type relationships that are produced by the **BIT**. It is rare to find a property database that provides sufficient information to define reliable mappings to all general building types.

To define a mapping, click on a building type in the **Source** list box and then double-click on the corresponding standardized building type in the **Target** list box. You can not map multiple building types at the same time in the **Source** list box that correspond to a single standardized building type. If you find you have made a mistake any time during this process, simply click on the incorrect mapping in the **Mapping Results** box and click on the **Delete** button. Redefine the correct mapping for that building type and continue.

When you have completed the mapping for all categories in the source database, click the **OK** button. At this point the **BIT** will check if the the Design Level was mapped at the field mappings or not if not it will go to Step 8.5.5 else it will go to step 8.6.6

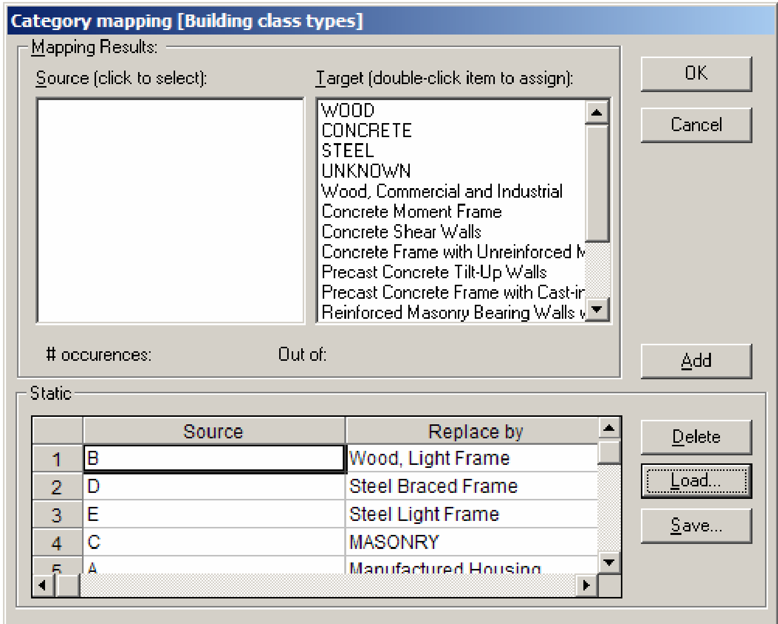


Figure 8.19 Categorizing building type data

As with other mappings defined in the **BIT**, you have the option to save the building type mapping for use on other files. To save the mapping, click on the **Save...** button before clicking **OK**. The building type mapping file will be saved with a .bsl extension as shown in Figure 8.20. To use the mapping in the future, click on the **Load...** button in Figure 8.19.

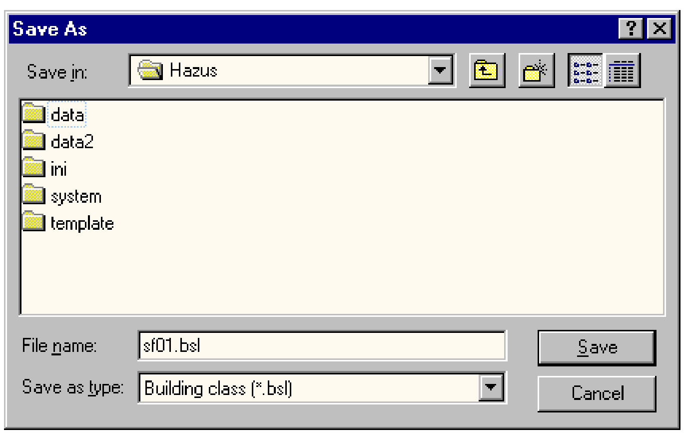


Figure 8.20 Saving a building type mapping scheme

8.5.5 Categorizing Design Level (Optional)

This step is required if you have not specified the Design Level Field mapping. In this step you will be required to map the design level found in the source database to the design level defined in **HAZUS.** There are 3 types of design levels defined in **HAZUS** **low**, medium and high as shown in Figure 8.21

To define a design level, click on a design level in the **Source** list box and then double-click on the corresponding design level in the **Target** list box. You can not map multiple design levels at the same from the design levels in the **Source** list box that correspond to a single design level. If you find you have made a mistake any time during this process, simply click on the incorrect mapping in the **Mapping Results** box and click on the **Delete** button. Redefine the correct mapping for that design level and continue.

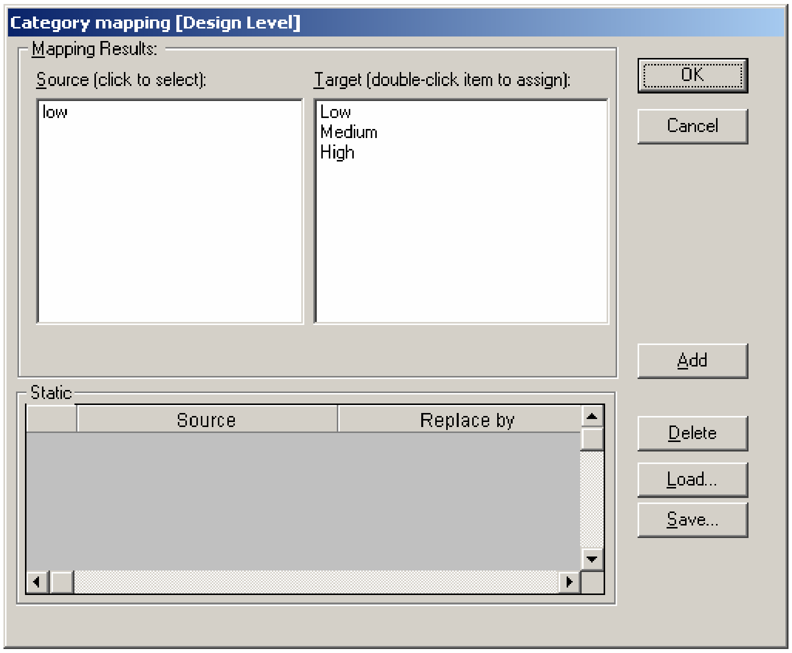


Figure 8.21 Categorizing Design Level

As with other mappings defined in the **BIT**, you have the option to save the design level mapping for use on other files. To save the mapping, click on the **Save...** button before clicking **OK**. The design level mapping file will be saved with a .dsl extension as shown in Figure 8.22. To use the mapping in the future, click on the **Load...** button in Figure 8.21.

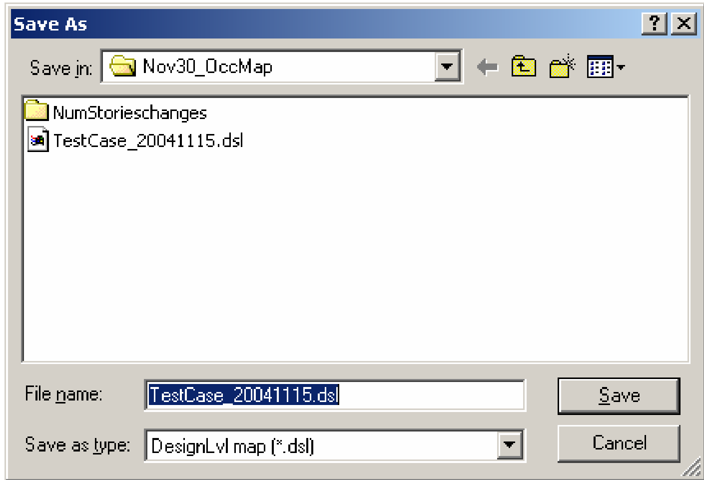


Figure 8.21 Saving a Design level type mapping

When you have completed the mapping for all categories in the source database, click the **OK** button.

8.5.6 Categorizing Floor Area

HAZUS uses Area in thousands of square feet. However, it is possible the field is numeric but not in the thousands of square feet. You can use a conversion factor as shown in Figure 8.23.

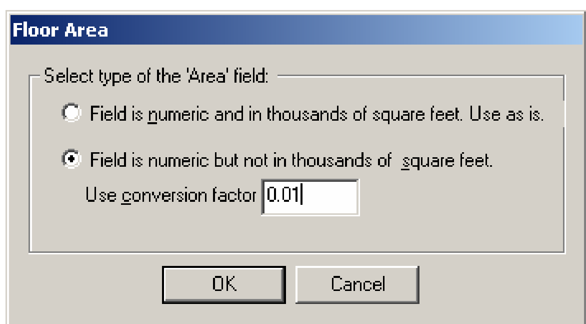


Figure 8.23 Categorizing Floor Area Data

When you have defined the type, click the **OK** button.

8.5.7 Categorizing Building Value

HAZUS uses builing values in thousands of dollars. However, it is possible field is numeric but not in the thousands of dollars. You can use a conversion factor as shown in Figure 8.24.

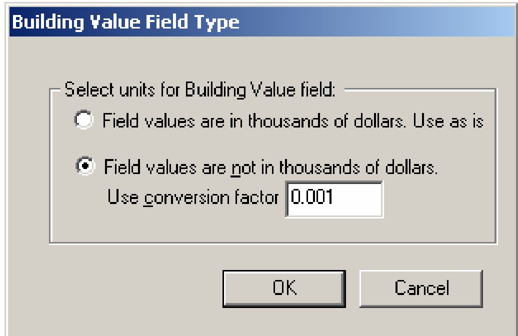


Figure 8.24 Categorizing Building Value data

When you have defined the type, click the OK button.

8.5.8 Categorizing Content Values

HAZUS uses Content Values in thousands of dollars. However, it is possible field is numeric but not in the thousands of dollars. You can use a conversion factor as shown in Figure 8.25.

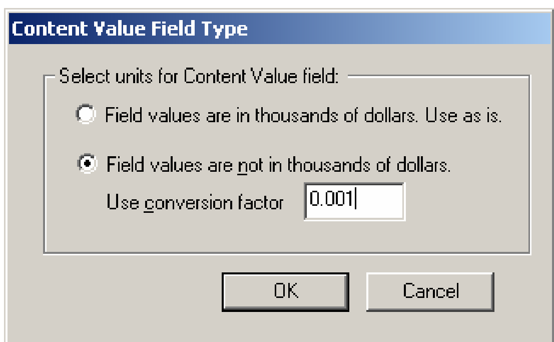


Figure 8.25 Categorizing Content Values data

When you have defined the type, click the OK button.

At this point the BIT will substitute the standardized categories for the original categories in the source database. Depending on the size of the database this will take a few minutes to more than an hour

8.6 Aggregating the Database Statistics

At this point the **BIT** is ready to create the occupancy to model building type relationships for each census tract. Click on the **Aggregate** button (shown in Figure 8.26) and wait. When the aggregation is done you will be able to view the results using the **View Results** button.

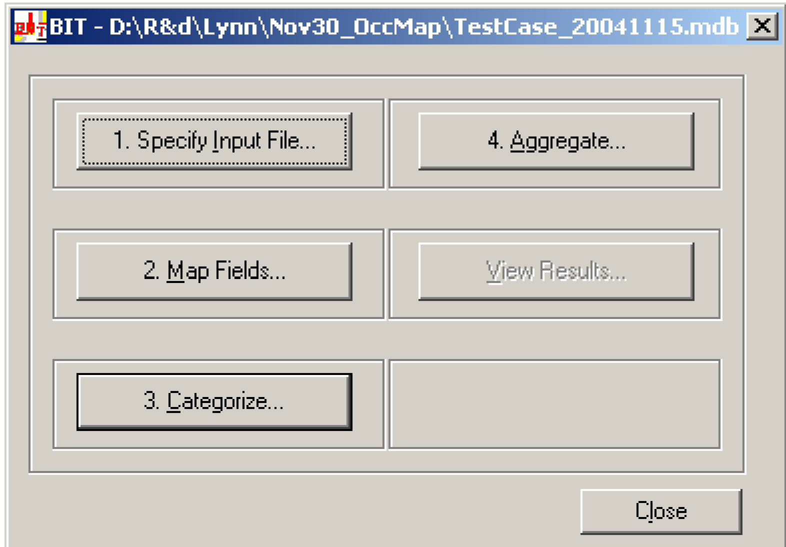


Figure 8.26 Starting the aggregation utility

If for some reason you have changed your database in some way and need to run the aggregate utility again, you will execute the exact same steps and BIT will update the data automatically.

8.7 BIT-MH Results

Once the aggregation process has finished, BIT-MH would have created the following type of results:

- Square footage values by specific occupancy
- Building structural and content dollar exposure values by specific occupancy
- Building count values by specific occupancy
- General mapping schemes (specific building type vs. general occupancy)
- Mapping scheme distrubtion matrices applicable to the earthquake module (specific building type vs. specific occupancy)

All of the above can then be imported into HAZUS to replace the default data. To get guidance on the process, contact Technical Support.

Chapter 9. Running HAZUS with User Supplied Data

Chapter 9 provides you with a step-by-step discussion of how to perform an analysis if you wish to modify default parameters and data. Before attempting an analysis that will incorporate user-supplied data, follow the steps in Chapter 3 for running an analysis using only the default data.

9.1 Defining the Study Region

The first step in any analysis is defining a study region. Defining a study region was discussed in Section 3.1.

9.2 Defining the Potential Earth Science Hazards

Section 3.2 gave a brief overview of how to define a scenario earthquake. **HAZUS** has a number of options for defining the potential earth science hazards (PESH). It also allows you to estimate losses based on one of three characterizations of the earthquake hazard:

- Scenario earthquake (deterministic hazard),
- Probabilistic seismic hazard analysis
- User-supplied map of ground motion

The **deterministic hazard** can be a historical epicenter event, a source event, or an arbitrary event:

- Historical Epicenter Event: The historical epicenter event definition consists of selecting the desired event from the **HAZUS** database of 3,500 historical events. The database includes a magnitude and depth, both of which can be overridden. The desired event can be picked either through a list box or graphically from a map.
- Source Event: For the Western United States, the source event definition consists of selecting the desired fault source from the **HAZUS** database of faults. The user can override the width, type, magnitude, and rupture length of the selected source event. The user graphically defines the epicenter of the event (on the fault).
- Arbitrary Event: An arbitrary earthquake event is defined by the location of its epicenter and by its magnitude. The epicenter is defined either by entry of latitude and longitude or graphically on a map. The user specifies the magnitude, depth, type, rupture orientation and length (for the Western U.S.) .

The **probabilistic hazard** option allows the user to generate estimates of damage and loss based on probabilistic seismic hazard for eight return periods. An additional option in **HAZUS** that is defined through the probabilistic hazard is the **Annualized Loss**. Annualized loss is defined as the expected value of loss in any one year, and is developed by aggregating the losses and their exceedance probabilities. Refer to Chapter 15 of the *Technical Manual* for more details.

The **user-supplied hazard** option requires the user to supply digitized peak ground acceleration (PGA) and spectral acceleration (SA) contour maps. Spectral accelerations at 0.3 second and 0.1 second (SA at 0.3 and SA at 1.0) are needed to define the hazard.

The damage and losses are computed based on the user-supplied maps. Refer to **Appendix J** for instructions about how to convert shape file based user supplied hazard maps or shake maps to corresponding GeoDatabases based user supplied hazard maps that could be used with **HAZUS**.

9.2.1 Defining Earthquake Hazard

Figure 9.1 shows the hazard definition menu. Again note that the hazard cannot be defined until the study region has been created (see Section 3.1). Clicking on the **Scenario** option allows you to define the earthquake hazard using the Scenario Wizard, shown in Figure 9.2.

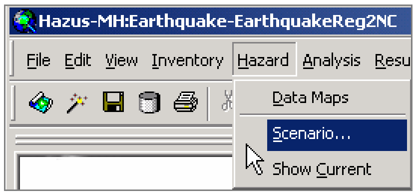


Figure 9.1 Hazard definition menu in HAZUS.

If you have not already defined a scenario, the only menu option offered is to define one. The window in Figure 9.2 will open for you to define a deterministic, probabilistic, or user-supplied seismic hazard. When prompted, choose **Define a new scenario** or **Use an already pre-defined scenario** (see Figure 9.3).

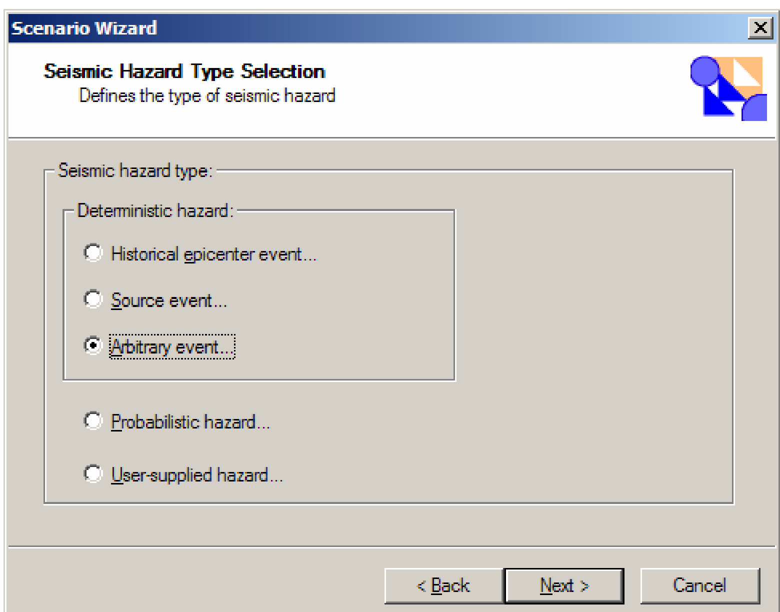


Figure 9.2 Define the ground motion event.

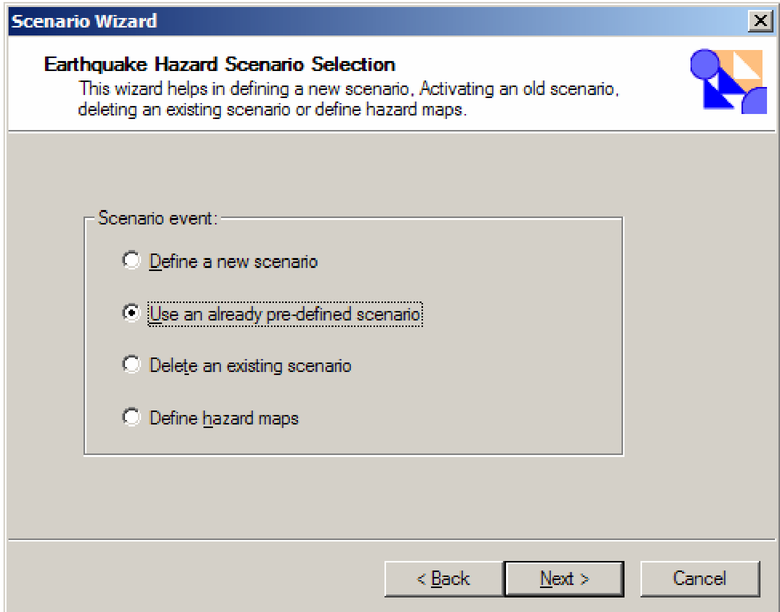


Figure 9.3 Open a pre-defined seismic hazard.

If you have previously run a scenario for a study region and you want to recall this scenario event for analysis on another study region, you can choose a predefined scenario event. When you select **Use an already pre-defined scenario**, you will be prompted with the window shown in Figure 9.4. Use the drop down menu to choose any of the scenarios that have been previously defined.

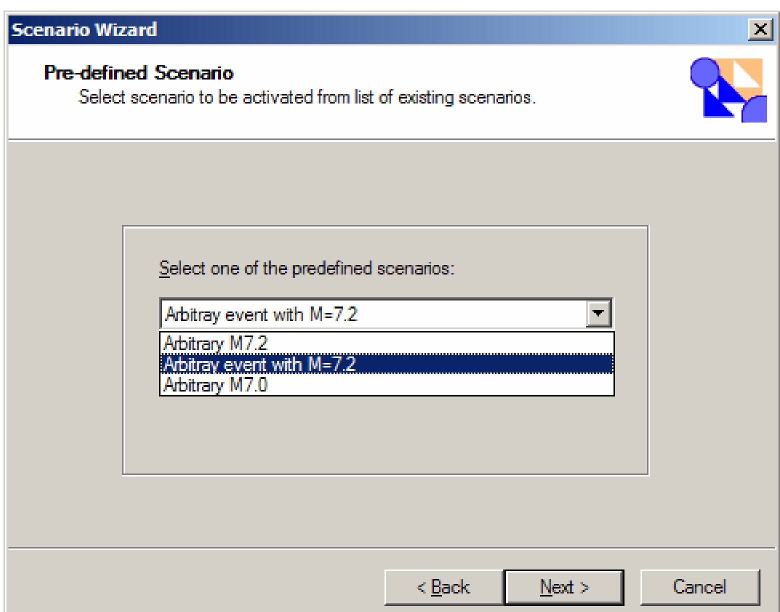


Figure 9.4 Select a pre-defined seismic hazard.

9.2.2 Defining a Deterministic Scenario

The three methods of defining a deterministic scenario are discussed in the following sections.

9.2.2.1 Historical Epicenter

Select the option **Historical epicenter event** from the seismic hazard definition menu shown in Figure 9.2. Click the **Next>** button and a window (see Figure 9.5) displaying the earthquake epicenter database will appear. Choose the historical event from the database and click **Next**.

Alternatively, select the historical epicenter from a map (Figure 9.6) by clicking the right mouse button on the event record of general interest. Select **Map** from the option list and a window will open with historical epicenters plotted (not labeled). Select an epicenter for analysis using the select button on the toolbar. Click the left mouse button once, directly over the epicenter of interest. Choose **Selection Done** to return to the list, where the selected epicenter record will be highlighted. The list will contain epicenter details: fault name, state, magnitude, fault depth (kms), event date, epicenter latitude/longitude, source of event information.

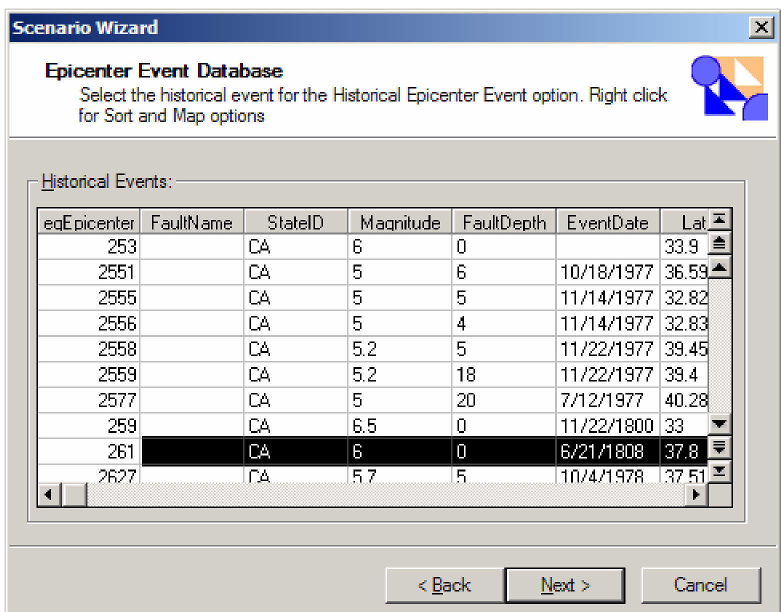


Figure 9.5 Select historical seismic event.

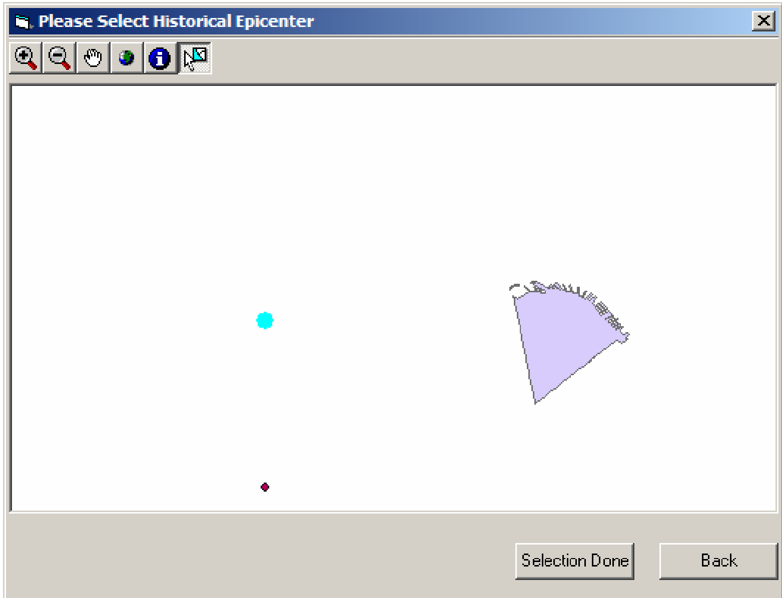


Figure 9.6 Select epicenter from map.

Confirm your event selection by clicking on **Next>**. You will be prompted to select an attenuation function, which may be chosen from the list (see Figure 9.7). The next dialogue window (see Figure 9.8) will allow you to edit additional event parameters. Accept, or edit the seismic event parameters given.

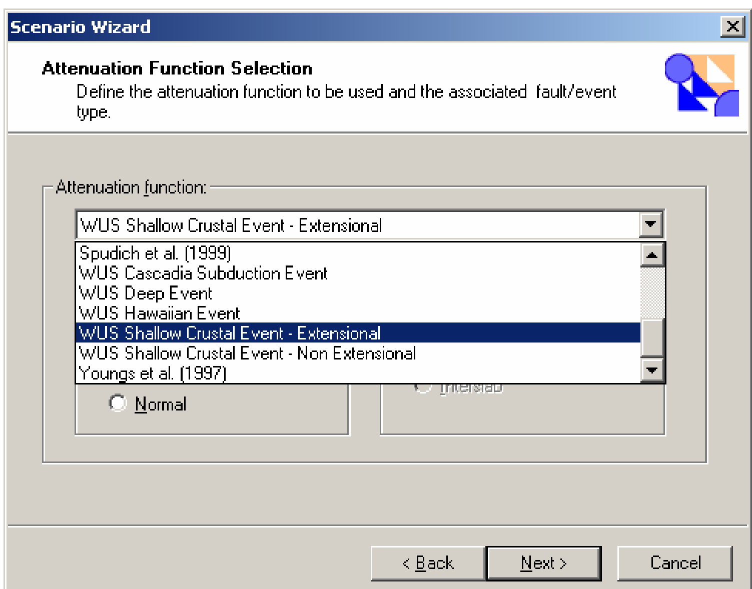


Figure 9.7 Attenuation functions.

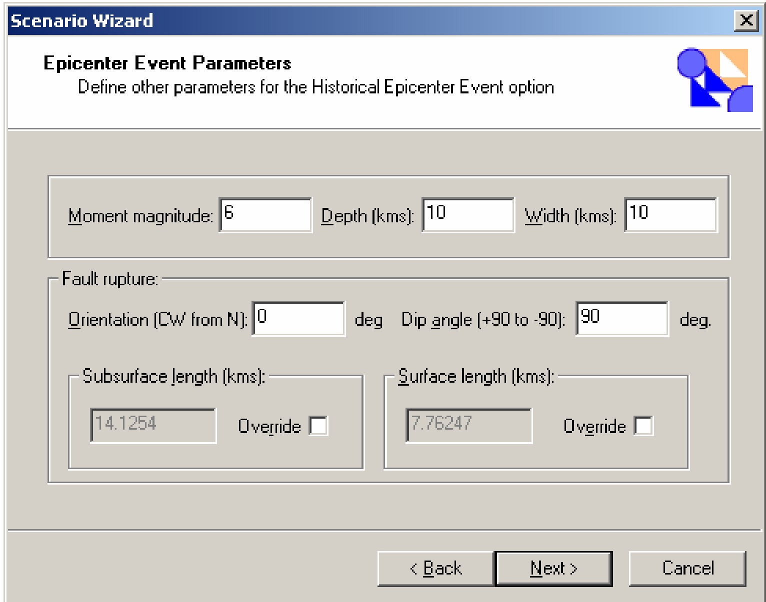


Figure 9.8 Accept or edit epicenter event parameters.

Rupture orientation is measured in degrees (0 to 360) clockwise from North. Rupture length is based on the default magnitude versus rupture length relationship (Wells and Coppersmith, 1994) unless you choose to override it. If you change the magnitude of the historical earthquake, **HAZUS** computes a new rupture length to correspond to the new magnitude.

9.2.2.2 Fault Source Event

A database of faults used by the USGS in "Project 97" is supplied with **HAZUS**. Using the **Hazard|Scenario** menu, select **Define a new earthquake scenario**, and then **Source event**. The window in Figure 9.9 describes the historic fault database and provides several options from which to choose. Due to licensing issues, the earthquake fault database distributed with **HAZUS** does not include California faults. If the California faults are needed, select the second option "I need the California faults. Tell how to get the full database" to get the instructions about the process for obtaining the password to unlock the CA faults.

If you do need California fault records, or think you might in the future, select one of the remaining options.

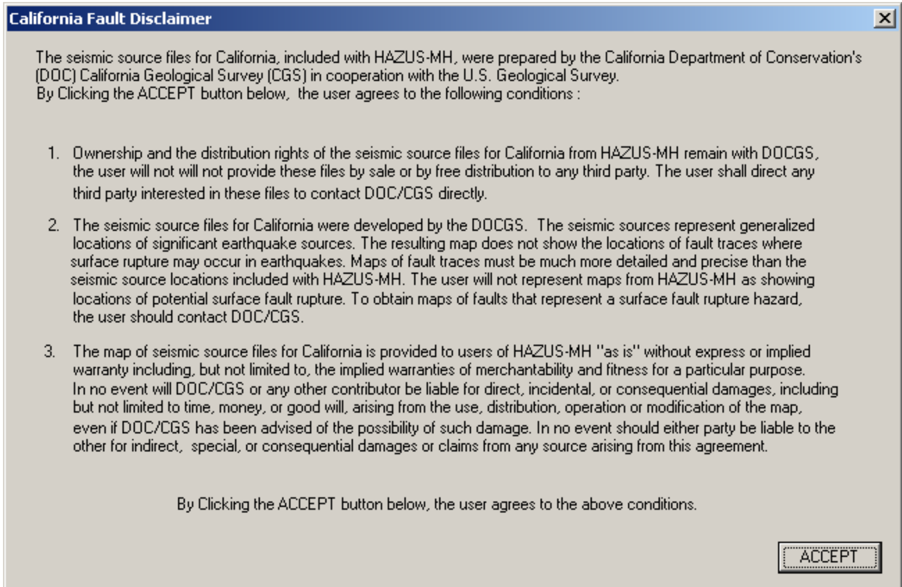


Figure 9.9 Access to historical fault database.

Select a fault when presented with the fault database, as in Figure 9.10, or use the **Map** option (available through the context menu by right-clicking) to select the fault graphically from a map. The scenario earthquake can then be located anywhere along the selected fault. Each source is given a source number and the database is presented so that sources are in numerical order. If you wish to sort the database in some other order, highlight the desired column by clicking on the title at the top of the column and then click **Sort** from the context menu. For example to sort the database in alphabetical order, highlight the fault name column and sort.

Once a source has been selected from the source database, you can define the location of the epicenter. Click the **Define** button in the next wizard page. You will then be presented with a map of sources. The scenario event epicenter is defined by clicking on a location on the map. Magnitude and rupture length are then defined the same as they were in Figure 9.8.

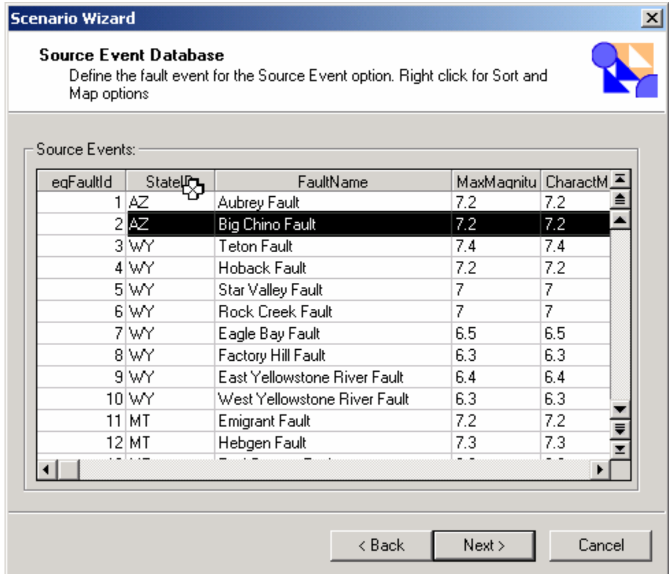


Figure 9.10 Selecting the fault from the HAZUS source database.

9.2.2.3 Arbitrary Event

If you have chosen the **Arbitrary event** option (see Figure 9.2), you will use the dialog box shown in Figure 9.11 to define the location, magnitude, epicenter depth, rupture orientation and rupture length. The latitude/longitude of the epicenter can be typed in the data entry fields, or defined on the region map with the **Map** button. Rupture orientation is measured in degrees (0 to 360) clockwise from North.

Rupture length is based on the default magnitude versus rupture length relationship (Wells and Coppersmith, 1994) unless you choose to override it. Only if your analysis is being done for an area in western U.S. and applies an attenuation function for the region, will you be given an option to edit the fault rupture length. When this is the case, you can change the magnitude of the earthquake, then click on the **Override** button. **HAZUS** will compute a new rupture length to correspond to the new magnitude.

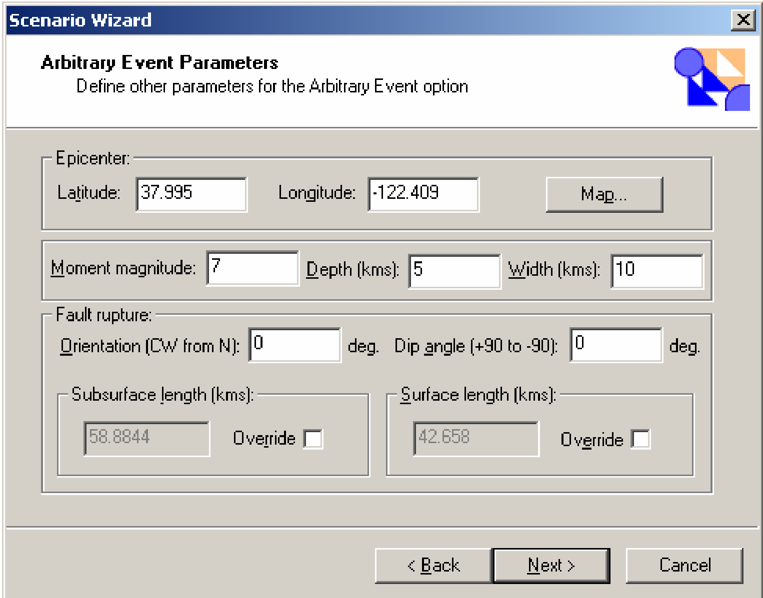


Figure 9.11 Define parameters for an arbitrary event.

9.2.3 Defining Probabilistic Hazard

The user can select a scenario based on ground shaking data derived from the USGS probabilistic seismic hazard curves. The probabilistic analysis option is available for eight return periods[12] of ground shaking. The user specifies the desired return period through the drop down menu in Figure 9.12. Alternatively, the user can select the **Annualized Loss** option (see Figure 9.12) to estimate average annualized losses for the general building stock and casualties. The default assumption is an **M**=7.0 earthquake. If the user has concerns with the appropriateness of the default magnitude assumption, consult a local earth science expert or call the technical support line for **HAZUS** at 1-800-955-9442.

[12] The eight return periods are: 100-year, 250-year, 500-year, 750-year, 1000-year, 1500-year, 2000-year, and 2500-year.

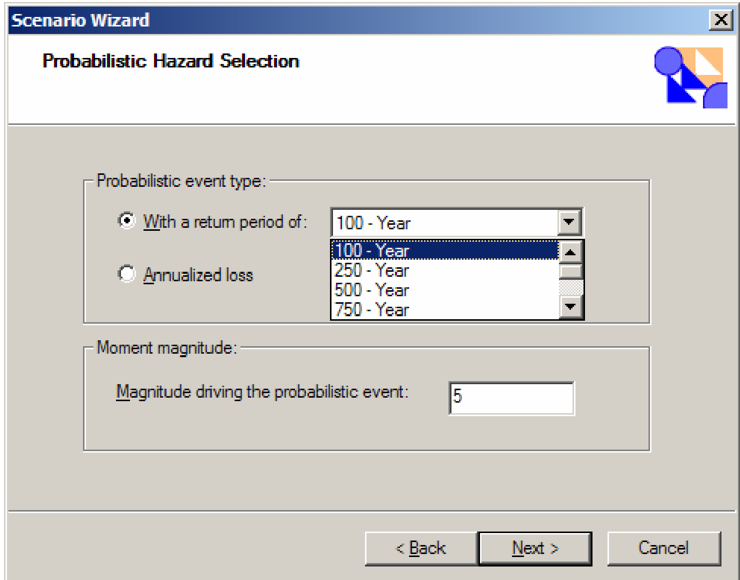


Figure 9.12 Probabilistic Hazard Options window.

9.2.4 User-defined Hazard

The user can supply the ground shaking maps for estimating damage and loss. The ground shaking maps must be in geodatabase format and be added to the list of available data maps defined under using the **HAZUS** menu **Hazard|Data Maps** (see Figure 9.13). The following is a list of optional ground shaking and Potential Ground Displacement (PGD) maps that may be used to define the hazards:

- Landslide Probability
- Liquefaction Probability
- Surface Fault Rupture Probability
- PGD due to Lateral Spreading from Landslide
- PGD due to Settlement from Liquefaction
- PGD due to Surface Fault Rupture

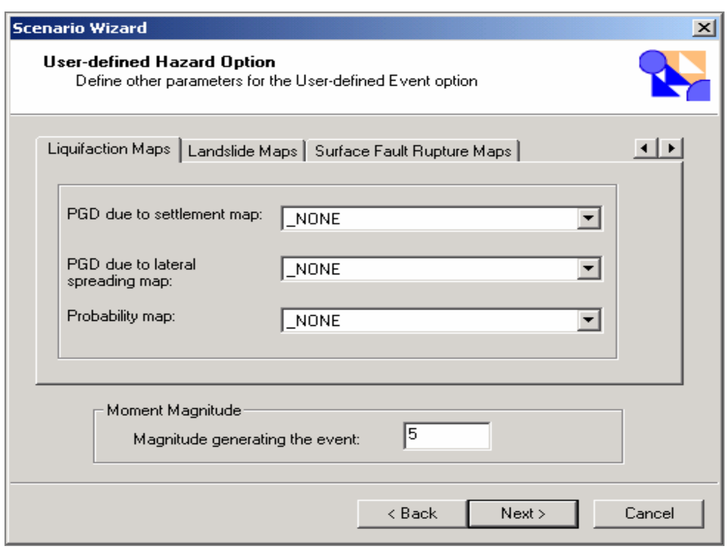


Figure 9.13 Apply user-defined ground shaking maps.

9.2.5 Choosing an Attenuation Function

HAZUS contains default attenuation relationships that define how ground motion decreases as a function of distance from the source. For the Western United States, ten attenuation functions are available. For the Eastern United States, four attenuation relationships are available. The user can select any relevant attenuation relationship used in the analysis (see Figure 9.7). Detailed descriptions of the available attenuation relationships are provided in Chapter 4 of the *Technical Manual*.

9.2.6 Selecting An Earthquake Scenario

A scenario earthquake is defined by its size and location and in cases where a fault is well defined, a rupture length. Earthquake size is measured in **HAZUS** by moment magnitude (**M**). Location is defined by latitude and longitude. It is important to note that the scenario event does not have to occur within the defined study region. The rupture length is measured in kilometers. **HAZUS** uses a relationship between rupture length and magnitude (Wells and Coppersmith, 1994) to estimate the default rupture length.

Rupture length is automatically computed by **HAZUS**, but can be overwritten by the user when the analysis is being done in the western states with western attenuation functions. A description of the technical approach to defining an earthquake scenario is provided in Chapter 4 of the *Technical Manual*.

Four approaches to selecting a scenario earthquake are described in the following sections:

- Largest Historical Earthquake
- Largest Possible Earthquake
- Maximum Possible Earthquake + Smaller, More Frequent Event
- Earthquake Scenario from a Previous Study

9.2.6.1 Largest Historical Earthquake

One approach is to base the scenario earthquake on the largest earthquake known to have occurred in or near the region. This assumes that if such an earthquake has occurred before, it can occur again. **HAZUS** includes a database of historic earthquakes (see Figure 9.5) based on the Global Hypocenter Database available from the National Earthquake Information Center (NEIC, 1992). The NEIC database contains reported earthquakes from 300 BC to 1990. You can access this database by clicking on **Historical epicenter event** (see Figure 9.5), and then selecting an historic earthquake for the scenario event. If several active faults exist in the region, it is appropriate to select maximum historical events from each fault and to perform a loss study for each of these scenarios.

Once an event based on an historical epicenter has been chosen, you can run the analysis with that event or modify the earthquake using the window shown in Figure 9.8. You have the option to change the magnitude, the earthquake depth, the rupture length and the orientation of the rupture. The location of the event cannot be changed if an historical epicenter has been chosen. If you wish to use a different location you must select a different historical event or use the “Arbitrary Event” option.

9.2.6.2 Largest Possible Earthquake

Another approach to selecting a scenario earthquake is to use the largest event that could possibly occur in the study region. This earthquake would be at least as large, and may in fact be larger than the largest historical event. In this case the size of the event would depend on geologic factors such as the type, length and depth of the source. Except in cases where the maximum possible event is well documented in published literature, a seismologist would be required to define this earthquake.

9.2.6.3 Maximum Possible + Smaller Event

In some of the past studies, two levels of earthquakes have been used: an historical maximum earthquake or a maximum possible earthquake, and a smaller earthquake chosen by judgment. The smaller earthquake has often been defined to have a magnitude one unit less than the historical maximum earthquake. Recommendations in the 1989 National Research Panel Report (FEMA, 1989) are that the scenario event should be relatively probable, yet damaging. The Panel found that the use of a very large but very infrequent earthquake could cause rejection of loss estimates. Use of a frequent but small event provides little useful information. The user may wish to select a scenario earthquake that has a probability of occurrence associated with it. An example would be an earthquake that has X% probability of occurrence in the next Y years. This probability can then be used to express the likelihood that the estimated losses will occur.

9.2.6.4 Earthquake Scenario from Previous Study

Another approach is for the user to base loss estimates on an earthquake that was used in a previous loss study. Problems that can occur with this approach are that some previous studies are based upon using **Modified Mercalli Intensity** (MMI) to define the scenario earthquake. Modified Mercalli Intensity is a system for measuring the size of an earthquake (from I to XII) based upon the damage that occurs. For example an MMI of VI indicates that some cracks appear in chimneys, some windows break, small objects fall off shelves and a variety of other things occur. MMI is not based on instrumental recordings of earthquake motions and does not easily correlate with engineering parameters, thus MMI is not used in **HAZUS**. A seismologist would be required to convert maps, or other MMI based data to moment magnitude or spectral response for it to be used in **HAZUS**.

9.2.7 Viewing the Current Defined Hazard

At any time during data entry, analysis or viewing of results, you can view the parameters that define the selected hazard by clicking on the **Hazard|Show Current** option on the **HAZUS** menu bar. An example of the displayed summary is found in Figure 9.14.

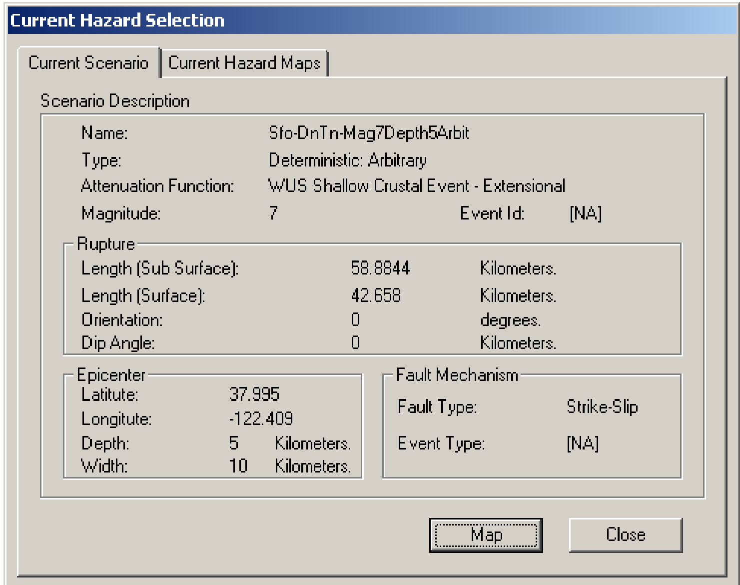


Figure 9.14 Viewing the parameters of the current hazard definition.

9.2.8 Including Site Effects

The type of soil in the study region can affect the amplitude of the ground motion. Soft soils tend to amplify certain frequencies within the ground shaking, resulting in greater damage. To include the effects of soils, the user must supply a soil map. If a soil map is not supplied, **HAZUS** bases ground motions on a default soil type. A digitized soil map can be entered into **HAZUS** using the steps outlined in Chapter 6. Refer to **Appendix K** for instructions about how to convert shape file based soil map to corresponding GeoDatabases based soil map that could be used with **HAZUS**.

There are a variety of schemes for classifying soils, but only one standardized classification scheme is used in **HAZUS**. The site classes are summarized in Table A.1 of Appendix A. The default soil class for **HAZUS** is soil Class D. Many available soil maps do not use the classification scheme shown in Table A.1. In this case, a geotechnical engineer or geologist will be required to convert the classification scheme of the available soil map to that shown in Table A.1.

9.2.9 Including Ground Failure

Three types of ground failure are considered in **HAZUS**: liquefaction, landsliding and surface fault rupture. Each of these ground failure types are quantified by **permanent ground displacement** (PGD) measured in inches.

Liquefaction is a soil behavior phenomenon in which a saturated soil looses a substantial amount of strength causing the soil to behave somewhat like a liquid. As a result soil may boil up through cracks in the ground and may lose most of its strength and stiffness. This can cause uneven settlement of the soil, or spreading of the soil. The result is that structures founded on soils that have liquefied tend to have more damage than those on other types of soils. This can be particularly significant in the case of lifelines, where roads become bumpy, cracked and unusable or underground pipes break because of liquefaction. Silty and clayey soils tend to be less susceptible than sandy soils to liquefaction-type behaviors.

Permanent ground displacements, due to lateral spreads or flow slides and differential settlement, are commonly considered significant potential hazards associated with liquefaction. Lateral spreads are ground failure phenomena that occur near abrupt topographic features (i.e., free-faces) and on gently sloping ground underlain by liquefied soil. Lateral spreading movements may be on the order of inches to several feet or more, and are typically accompanied by surface fissures and slumping. Flow slides generally occur in liquefied materials found on steeper slopes and may involve ground movements of hundreds of feet. As a result, flow slides can be the most catastrophic of the liquefaction-related ground-failure phenomena. Fortunately, flow slides are much less common occurrences than lateral spreads.

Settlement is a result of particles moving closer together into a denser state. This may occur in both liquefied and non-liquefied zones with significantly larger contributions to settlement expected to result from liquefied soil. Since soil characteristics vary over even relatively small areas, settlements may occur differentially. This differential settlement can cause severe damage to structures and pipelines as it may tend to tear them apart.

9.2.9.1 Liquefaction

To include liquefaction in the analysis, you may specify a liquefaction susceptibility map using the steps outlined in Chapter 6 of this manual. There are three steps involved in the evaluation of liquefaction hazard:

1. Characterize liquefaction susceptibility (very low to very high)
2. Assign probability of liquefaction
3. Assign expected permanent ground deformations

A liquefaction susceptibility map, showing the susceptibility for each census tract, is a result of the first step. An experienced geotechnical engineer, familiar with both the region and with liquefaction, should be consulted in developing this map. The relative liquefaction susceptibility of the soil (geologic conditions) in a region or sub-region is characterized by using geologic map information and the classification system presented in Table 9.1. High resolution (1:24,000 or greater) or lower resolution (1:250,000) geologic maps are generally available for many areas from geologists or regional US Geological Survey offices, state geological agencies, or local government agencies. The geologic maps typically identify the age, the environment of the deposit, and material type for a particular mapped geologic unit. A depth to groundwater map is also a helpful reference. Based on these characteristics, a relative liquefaction susceptibility rating (very low to very high) can be assigned from Table 9.1 to each soil type.

Based on the liquefaction susceptibility and the peak ground acceleration, a probability of liquefaction is assigned during the analysis (see Section 4.2 of the *Technical Manual*). Areas of geologic materials characterized as rock or rock-like are considered for the analysis to present no liquefaction hazard.

Finally, in order to evaluate the potential losses due to liquefaction, an expected permanent ground displacement (PGD) in the form of ground settlement or lateral spreading is assigned. The PGD is based on peak ground acceleration and liquefaction susceptibility. **HAZUS** assigns PGD using a procedure derived from experience as discussed in the *Technical Manual*.

Table 9.1 Liquefaction Susceptibility of Sedimentary Deposits

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments when Saturated would be Susceptible to Liquefaction (by Age of Deposit)			
		< 500 yr Modern	Holocene < 11 ka	Pleistocene 11 ka - 2 Ma	Pre-Pleistocene 11 ka - 2 Ma
(a) Continental Deposits					
River channel	Locally variable	Very High	High	Low	Very Low
Flood plain	Locally variable	High	Moderate	Low	Very Low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very Low
Marine terraces and plains	Widespread	---	Low	Very Low	Very Low
Delta and fan-delta	Widespread	High	Moderate	Low	Very Low
Lacustrine and playa	Variable	High	Moderate	Low	Very Low
Colluvium	Variable	High	Moderate	Low	Very Low
Talus	Widespread	Low	Low	Very Low	Very Low
Dunes	Widespread	High	Moderate	Low	Very Low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very Low	Very Low
Tuff	Rare	Low	Low	Very Low	Very Low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very Low	Very Low
Sebka	Locally variable	High	Moderate	Low	Very Low
(b) Coastal Zone					
Delta	Widespread	Very High	High	Low	Very Low
Esturine	Locally variable	High	Moderate	Low	Very Low
Beach					
High Wave Energy	Widespread	Moderate	Low	Very Low	Very Low
Low Wave Energy	Widespread	High	Moderate	Low	Very Low
Lagoonal	Locally variable	High	Moderate	Low	Very Low
Fore shore	Locally variable	High	Moderate	Low	Very Low
(c) Artificial					
Uncompacted Fill	Variable	Very High	---	---	---
Compacted Fill	Variable	Low	---	---	---

9.2.9.2 Landslide

As with liquefaction, to include landslide in the analysis you must specify a landslide susceptibility map using the steps outlined in Chapter 6. There are three steps involved in the evaluation of landslide hazard:

1. Characterize landslide susceptibility (I to X))
2. Assign probability of landslide
3. Assign expected permanent ground deformations

A landslide susceptibility map, showing the susceptibility for each census tract, is a result of the first step. An experienced geotechnical engineer, familiar with both the region and with earthquake-caused landsliding, should be consulted in developing this map. The methodology provides basic rules for defined the landslide susceptibility based on the geologic group, ground water level, slope angle and the critical acceleration (a_c). Landslide susceptibility is measured on a scale of I to X, with X being the most susceptible. The geologic groups and associated susceptibilities are summarized in Table 9.2.

Once landslide susceptibility has been determined, **HAZUS** provides default values for probability of landsliding and expected PGD as a function of ground acceleration. Chapter 4 of the *Technical Manual* describes the procedure in detail.

Table 9.2 Landslide Susceptibility of Geologic Groups

Geologic Group		Slope Angle, degrees					
		0-10	10-15	15-20	20-30	30-40	>40
(a) DRY (groundwater below level of sliding)							
A	**Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone, $c' = 300$ psf, $\phi' = 35^o$)**	None	None	I	II	IV	VI
B	**Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone, $c' = 0$, $\phi' = 35^o$)**	None	III	IV	V	VI	VII
C	**Argillaceous Rocks (shales, clayey soil, existing landslides, poorly compacted fills, $c' = 0$ $\phi' = 20^o$)**	V	VI	VII	IX	IX	IX
(b) WET (groundwater level at ground surface)							
A	**Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone, $c' = 300$ psf, $\phi' = 35^o$)**	None	III	VI	VII	VIII	VIII
B	**Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone, $c' = 0$, $\phi' = 35^o$)**	V	VIII	IX	IX	IX	X
C	**Argillaceous Rocks (shales, clayey soil, existing landslides, poorly compacted fills, $c' = 0$ $\phi' = 20^o$)**	VII	IX	X	X	X	X

9.2.9.3 Surface Fault Rupture

When an earthquake occurs, it is possible that the fault rupture can extend from its initiation at some depth all the way to the ground surface. Many earthquakes do not exhibit evidence of rupture at the ground surface, particularly in the Eastern United States. Generally, surface fault rupture is observed only in the Western United States and Alaska. When it occurs, displacements due to surface fault rupture can be on the order of several meters and can be a significant contributor to damage if a structure crosses or is built on top of the fault rupture. Pipelines, roadways, bridges and railways that cross faults are vulnerable to surface fault rupture.

Surface fault rupture can be included by selecting the **Ground Failure** when the analysis is run. **HAZUS** provides a default relationship between moment magnitude (**M**) and the displacement in meters that can result from surface fault rupture (see the *Technical Manual* for more information). For any location along the fault rupture, fault displacement can occur, however, the amount of fault displacement is described by a probability distribution. Surface fault rupture is presented to the user in the form of PGD contour maps.

9.2.10 Modifying Potential Earthquake Susceptibility Hazard Parameters

Potential ground motion is calculated each time direct and indirect losses are estimated. Default ground motion and ground failure parameters can be modified using the windows shown in Figure 9.15 and Figure 9.16. These windows can be accessed through the **Analysis| Parameters|Hazard** option on the **HAZUS** menu bar. The window shown in Figure 9.15 is used to modify soil amplification factors. Soil amplication factors include Potential Ground Acceleration (PGA), Potential Ground Velocity (PGV), amplification at 0.3 seconds and at 1.0 seconds. These factors are discussed in the *Technical Manual*. It should be noted, however, that these parameters should not be modified unless you have expertise in seismology and geotechnical engineering.

As discussed in the *Technical Manual*, soil does not behave uniformly and in an area with very high susceptibility to liquefaction it is unlikely that the entire area will actually liquefy. In fact, liquefaction may appear in pockets with a large portion of the area remaining unaffected. A parameter is used to define the proportion of a geologic map unit that is likely to liquefy or landslide given its relative susceptibility. The window in Figure 9.16 is used to modify the parameter defaults. These factors are also found in the *Technical Manual*.

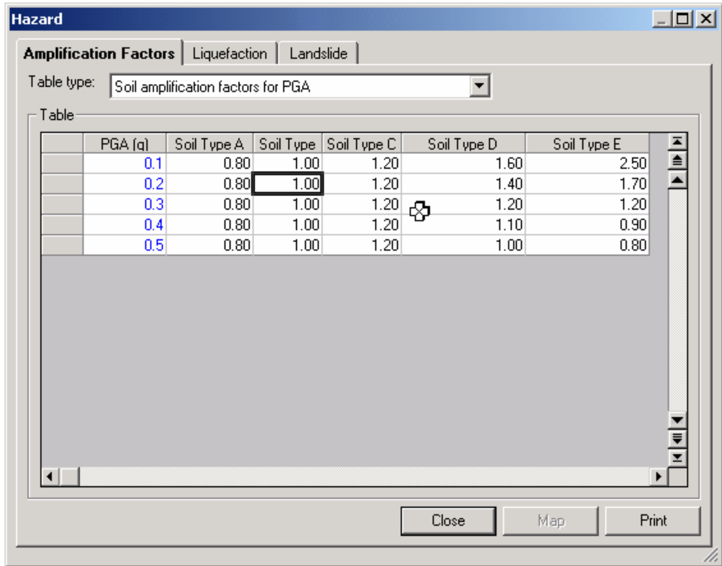


Figure 9.15 Modifying soil amplification factors.

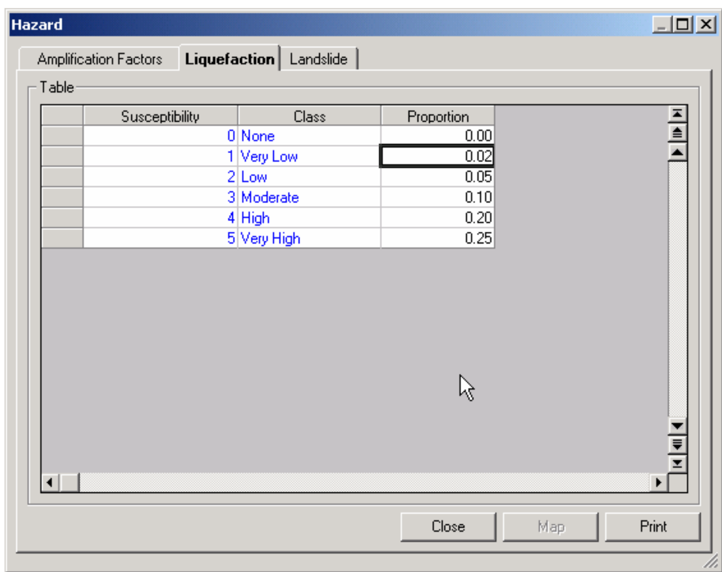


Figure 9.16 Modifying map areas susceptible to liquefaction.

9.3 Direct Physical Damage Analysis

Direct damage is estimated for structural and non-structural inventory; in particular, buildings and lifelines. The analysis menu options allow you to select which types of facilities and lifelines you want to have analyzed. If you want to run the analysis with default inventory and data, simply select the types of facilities to be analyzed. If you want to modify the default inventory before running your analysis, follow the instructions for modifying databases in Chapters 6 and 7 of this manual.

9.3.1 Structural Versus Non-structural Damage

HAZUS estimates direct damage to structural and non-structural building components separately. Structural components are the walls, columns, beams and floor systems that are responsible for holding up the building. In other words, the structural components are the gravity and lateral load resisting systems. Non-structural building components include building mechanical/electrical systems and architectural components such as partition walls, ceilings, windows and exterior cladding that are not designed as part of the building load carrying system. Equipment that is not an integral part of the building, such as computers, is considered **building contents**.

Damage to structural components affects casualties, building disruption, cost of repair and other losses differently than damage to non-structural components. For example, if the ceiling tiles fall down in a building, business operations can probably resume once the debris is removed. On the other hand, if a column in a building is damaged, there is a life safety hazard until the column is repaired or temporarily shored, possibly resulting in a long-term disruption. It should also be noted that the types of non-structural components in a given building depend on the building occupancy. For example, single-family residences would not have exterior wall panels, suspended ceilings, or elevators, while these items would be found in an office building. Hence, the relative values of non-structural components in relation to overall building replacement value vary with type of occupancy. In the direct economic loss module, estimates of repair and replacement cost are broken down by occupancy to account for differences in types of non-structural components.

Some non-structural components (partition walls and windows) tend to crack and tear apart when the floors of the building move past each other during the earthquake. As can be seen in Figure 9.17, the wall that extends from the first floor to the second floor is pulled out of shape due to the inter-story drift, causing it to crack and tear. In the methodology this is called **drift-sensitive non-structural damage**.

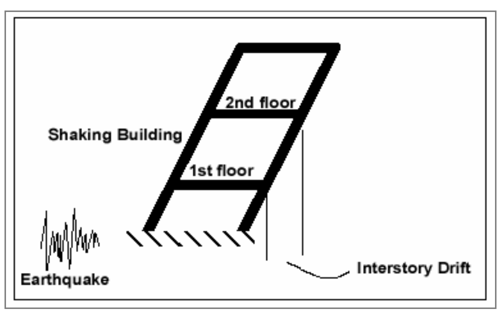


Figure 9.17 Inter-story drift in a shaking building.

Other non-structural components such as mechanical equipment tend to get damaged by falling over or being torn from their supports due to the acceleration of the building. This is similar to being knocked off your feet if someone tries to pull a rug out from under you. In the methodology this is called **acceleration-sensitive non-structural damage**. Of course many non-structural components are affected by both acceleration and drift, but for simplification, components are identified with one or the other as summarized in Table 9.3.

Table 9.3 Building Component Non-structural Damage

Type of Non-structural Damage	
Drift Sensitive	Acceleration Sensitive
• wall partitions • exterior wall panels and cladding • glass • ornamentation	• suspended ceilings • mechanical and electrical equipment • piping and ducts • elevators

9.3.2 Definitions of Damage States - Buildings

Damage estimates are used in **HAZUS** to estimate life-safety consequences of building damage, expected monetary losses due to building damage, expected monetary losses which may result as a consequence of business interruption, expected social impacts, and other economic and social impacts. The building damage predictions may also be used to study expected damage patterns in a given region for different scenario earthquakes, for example, to identify the most vulnerable building types, or the areas with the worst expected damage to buildings.

To serve these purposes, damage predictions must be descriptive. The user must be able to glean the nature and extent of the physical damage to a building type from the damage prediction output so that life-safety, societal and monetary losses that result from the damage can be estimated. Building damage can best be described in terms of the nature and extent of damage exhibited by its components (beams, columns, walls, ceilings, piping, HVAC equipment, etc.). For example, such component damage descriptions as “shear walls are cracked”, “ceiling tiles fell”, “diagonal bracing buckled”, or “wall panels fell out”, used together with such terms as “some” and “most” would be sufficient to describe the nature and extent of overall building damage.

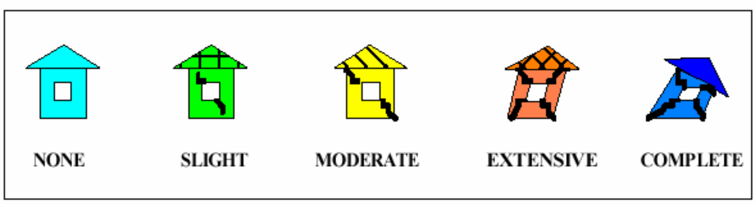


Figure 9.18 The five damage states.

Using the criteria described above, damage is described by five **damage states**: none, slight, moderate, extensive or complete (see Figure 9.18). General descriptions for the structural damage states of 16 common building types are found in the *Technical Manual*. Table 9.4 provides an example of the definitions of damage states for light wood frame buildings. It should be understood that a single damage state could refer to a wide range of damage. For example the **slight** damage state for light wood frame structures may vary from a few very small cracks at one or two windows, to small cracks at all the window and door openings.

Table 9.4 Examples of Structural Damage State Definitions

Wood, Light Frame
Slight : Small plaster or gypsum board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate: Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive: Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations; small foundations cracks.
Complete: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Damage to non-structural components is considered to be independent of building type. This is because partitions, ceilings, cladding, etc., are assumed to incur the same damage when subjected to the same inter-story drift or floor acceleration whether they are in a steel frame building or in a concrete shear wall building. Therefore as shown in the example in Table 9.5, descriptions of non-structural damage states are developed for common non-structural systems, rather than as a function of building type.

Table 9.5 Examples of Non-structural Damage State Definitions

Suspended Ceilings
Slight : A few Ceiling tiles may have moved or fallen down.
Moderate: Falling of tiles is more extensive; in addition the ceiling support framing (t-bars) may disconnect and/or buckle at a few locations; lenses may fall off a few light fixtures.
Extensive: The ceiling system may exhibit extensive buckling, disconnected t-bars and falling ceiling tiles; ceiling may have partial collapse at a few locations and a few light fixtures may fall.
Complete: The ceiling system is buckled throughout and/or has fallen down and requires complete replacement.

9.3.3 Definitions of Damage States - Lifelines

As with buildings, five damage states are defined: none, slight, moderate, extensive and complete. For each component of each lifeline a description of the damage is provided for each damage state. These descriptions are found in Sections 7.1 through 8.6 of the *Technical Manual*. An example of the damage state descriptions for electrical power system distribution circuits is found in Table 9.6

Table 9.6 Damage State Descriptions for Electrical Power System

Damage State	Damage Description
Slight	Failure of 4% of all circuits
Moderate	Failure of 12% of all circuits
Extensive	Failure of 50% of all circuits
Complete	Failure of 80% of all circuits

Damage states can be defined in numerical terms as is the case for distribution circuits or they can be more descriptive as shown in Table 9.7.

Table 9.7 Damage State Descriptions for Electrical Power System

Damage State	**Damage Description**
Slight	Turbine tripping, or light damage to diesel generator, or the building is in the slight damage state.
Moderate	Chattering of instrument panels and racks, or considerable damage to boilers and pressure vessels, or the building is in the moderate damage state.
Extensive	Considerable damage to motor driven pumps, or considerable damage to large vertical pumps, or the building is in the extensive damage state.
Complete	Extensive damage to large horizontal vessels beyond repair, or extensive damage to large motor operated valves, or the building is in the complete damage state.

9.3.4 Fragility Curves - Buildings

Based on the damage state descriptions described in the previous section and using a series of engineering calculations that can be found in the *Technical Manual*, **fragility curves** were developed for each building type. A fragility curve describes the probability of being in a specific damage state as a function of the size of earthquake input. For structural damage the fragility curves express damage as a function of building displacement (see Figure 9.19). The fragility curves express non-structural damage as a function of building displacement or acceleration, depending upon whether they refer to drift-sensitive or acceleration-sensitive damage.

Default fragility curves are supplied with the methodology. It is highly recommended that default curves be used in the loss studies. Modification of these fragility curves requires the input of a structural engineer experienced in the area of seismic design.

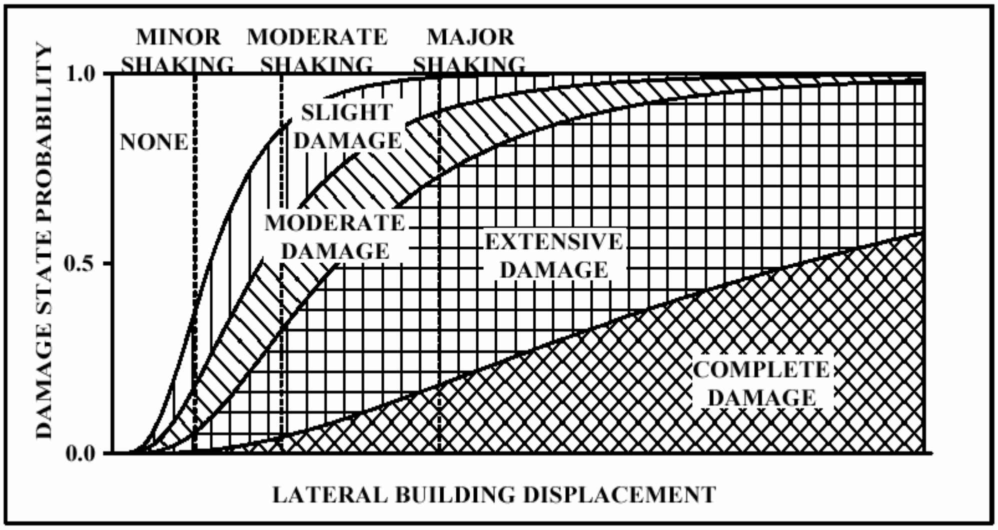


Figure 9.19 Sample building fragility curve.

9.3.5 Fragility Curves - Lifelines

As with buildings, default damage functions (fragility curves) have been developed for all components of all lifeline systems. Typical damage functions are shown in Figure 9.20 and Figure 9.21. The damage functions are provided in terms of PGA (Figure 9.20) and PGD (Figure 9.21). The top curve in Figure 9.20 gives the probability that the damage state is at least slight given that the bridge has been subjected to a specified PGA. For example, if the bridge experiences a PGA of 0.4g, there is a 0.7 probability that the damage will be slight or worse. Figure 9.21 is similar, except it is in terms of PGD. Thus if a bridge experiences a permanent ground deformation of 12 inches, there is a 100 percent chance that it will have at least slight damage and a 70% chance it will have moderate damage or worse.

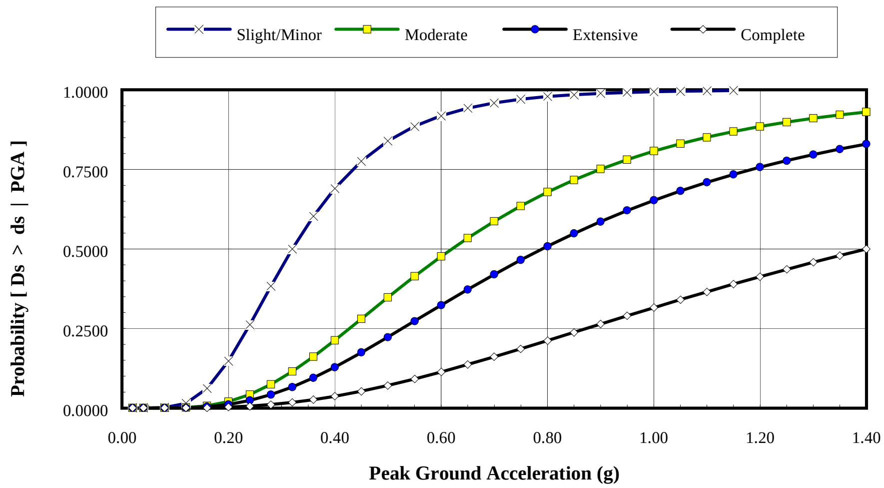


Figure 9.20 Fragility Curves at Various Damage States for Seismically Designed Railway Bridges Subject to Peak Ground Acceleration.

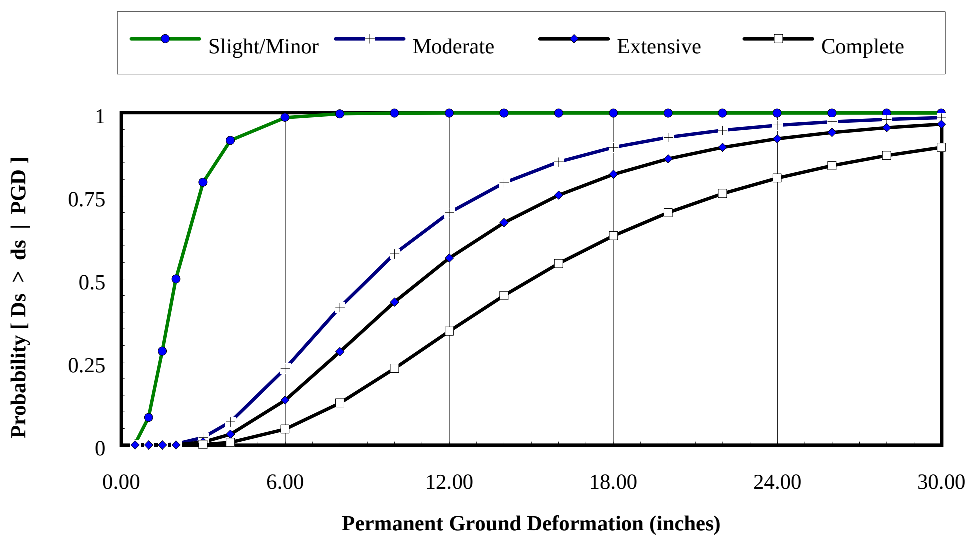


Figure 9.21 Fragility Curves at Various Damage States for Seismically Designed Railway Bridges Subject to Permanent Ground Deformation.

The default damage functions are lognormal with parameters (medians and betas) as defined in the *Technical Manual*. These parameters can also be viewed and modified using **HAZUS**. The window for viewing parameters of fragility curves for railway bridge system components is shown in Figure 9.22. In this example, parameters of damage functions for PGA induced damage are displayed. The user can also view parameters for PGD induced damage by moving to the right within the table. The column “PGASlightMedian” contains the median PGA (g’s) for the slight damage state. The median is defined as the value at which the probability is 0.99 for all railway bridge classes. Compare the slight damage fragility curve in Figure 9.20 with the parameters for the component RLB1 in Figure 9.22. The column "PGASlightBeta" contains the parameter Beta, which is an indicator the dispersion of the distribution. The larger the Beta the more spread out the fragility curve. The Beta for slight damage to RLB1 is 0.6. While these parameters can be modified, default values should be used unless an expert structural engineer experienced in seismic design is consulted.

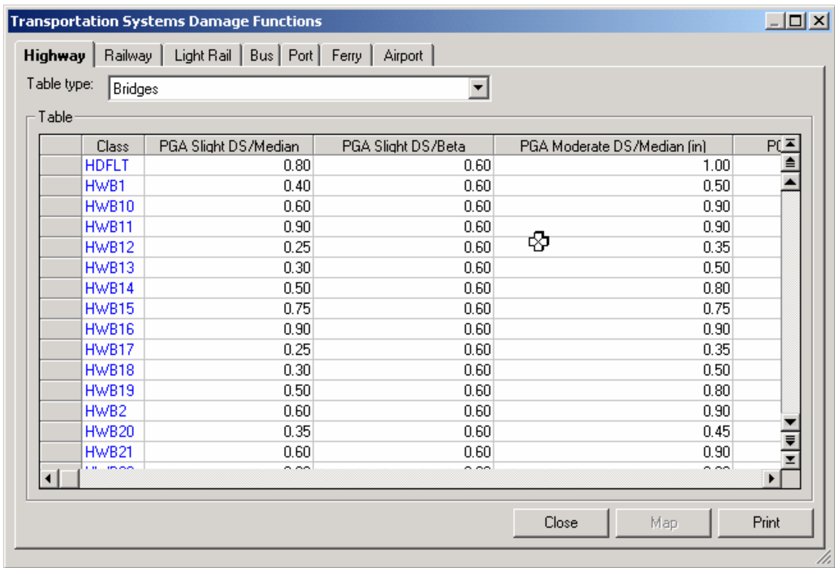


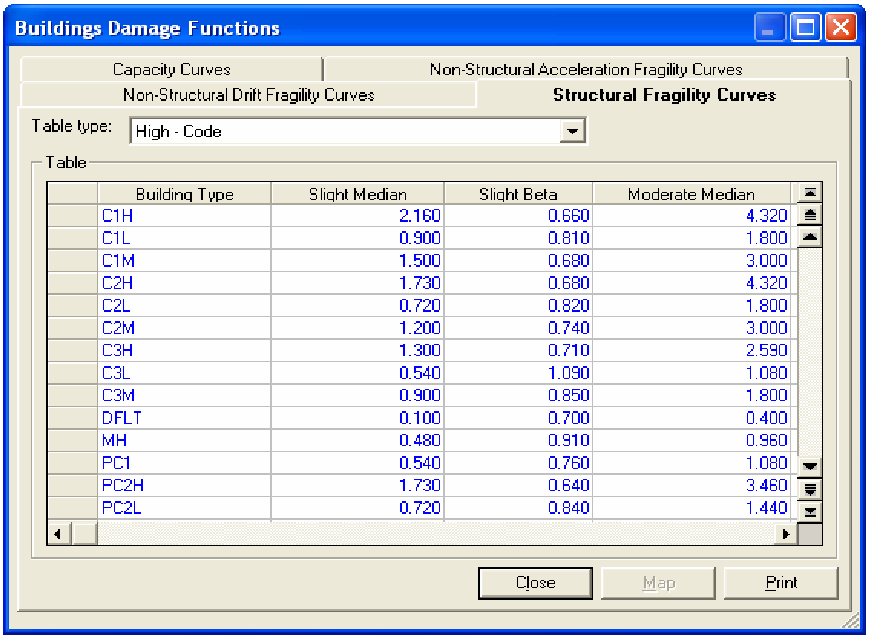
Figure 9.22 Parameters of lognormal damage functions, as viewed in HAZUS, for PGA induced damage to highway bridges.

9.3.6 Modifying Fragility Curves

The fragility curves described in the previous section are each characterized by a median and a lognormal standard deviation (β). There are two types of curves: those for which spectral displacement is the parameter describing earthquake demand and those for which spectral acceleration is the parameter. The first type of curve is used for estimating structural damage and drift-sensitive non-structural damage. The second type is for estimating acceleration sensitive non-structural damage.

Default fragility curves are provided for all model building types, essential facility model building types and for all lifeline components. Figure 9.23 shows an example of the parameters of fragility curves for model buildings with a high seismic design level. This window is accessed through the **Analysis|Damage Functions|Buildings** menu. Fragility curves are available for three seismic design levels and three construction standards for both structural and non-structural damage. (Note: Design levels and construction standards are discussed in the *Technical Manual*.) Fragility curves for lifelines are accessed through the **Analysis|Damage Functions| Transportation Systems** menu or the **Analysis| Damage Functions|Utility Systems** menu. Fragility curves are available for both PGA and PGD related damage.

Should you desire to modify the fragility curves, change the mean and beta in this window and then click on the **Close** button. You will be asked to confirm that you want to save your changes. Development of fragility curves is complex and is discussed in detail in the *Technical Manual*. It is <u>strongly</u> recommended that you use the default parameters provided unless you have expertise in the development of fragility curves.



Building Type	Slight Median	Slight Beta	Moderate Median
C1H	2.160	0.660	4.320
C1L	0.900	0.810	1.800
C1M	1.500	0.680	3.000
C2H	1.730	0.680	4.320
C2L	0.720	0.820	1.800
C2M	1.200	0.740	3.000
C3H	1.300	0.710	2.590
C3L	0.540	1.090	1.080
C3M	0.900	0.850	1.800
DFLT	0.100	0.700	0.400
MH	0.480	0.910	0.960
PC1	0.540	0.760	1.080
PC2H	1.730	0.640	3.460
PC2L	0.720	0.840	1.440

Figure 9.23 Parameters of building fragility curves.

9.3.7 Steps for Calculating Damage State Probabilities

There are several steps that are needed to calculate damage state probabilities:

1. Calculate the spectral accelerations and spectral displacements at the site in question. This is in the form of a response spectrum.
2. Modify the response spectrum to account for the increased damping that occurs at higher levels of building response (non-linear behavior).
3. Create a capacity curve for the model building type which shows how the building responds as a function of the laterally applied earthquake load.
4. Overlay the building capacity curve with the modified response spectrum (demand curve). The building displacement is estimated from the intersection of the building capacity curve and the response spectrum.

The estimated building displacement is used to interrogate the fragility curves. Figure 9.24 illustrates the intersection of the building capacity curve and a response spectrum that has been adjusted for higher levels of damping.

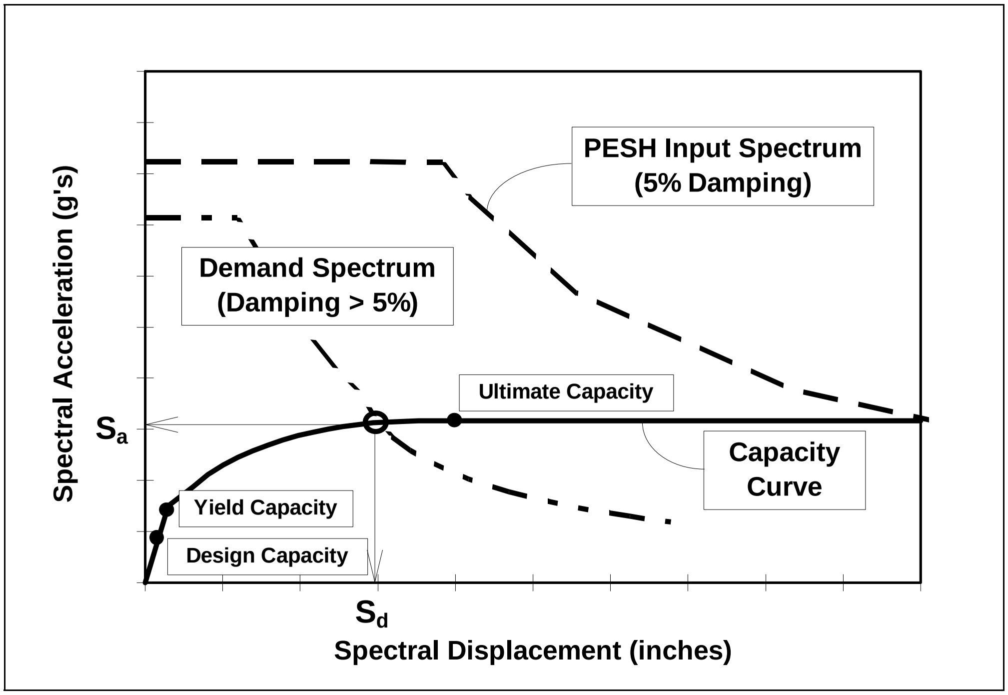
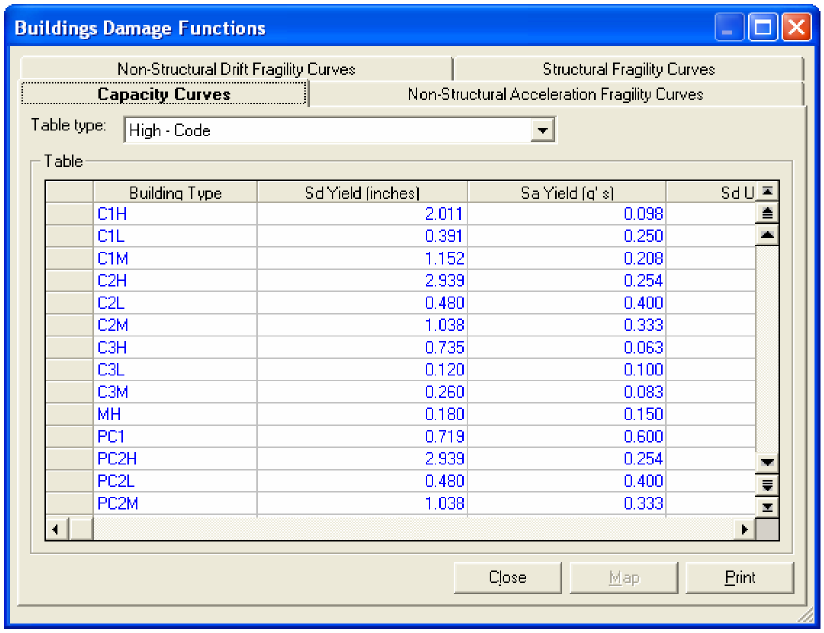


Figure 9.24 Example Capacity Curve and Spectral Demand.

9.3.8 Modifying Capacity Curves

Two points define capacity curves as shown in Figure 9.24: the yield capacity and the ultimate capacity. For general building stock, these parameters can be viewed, as shown in Figure 9.25, by clicking on the **Analysis|Damage Functions|Buildings** menu. Capacity curves are available for three levels of seismic design and three construction standards. Capacity curves are discussed in detail in *the Technical Manual*. To modify the capacity curves, modify the yield capacity, ultimate capacity spectral accelerations, and displacements. The edited values will be saved when you click on the **Close** button. You will be asked to confirm that you want to save your changes. It is strongly recommended that you use the default parameters unless you have expertise in the development of capacity curves.



Building Type	Sd Yield (inches)	Sa Yield (g' s)	Sd U
C1H	2.011	0.098	
C1L	0.391	0.250	
C1M	1.152	0.208	
C2H	2.939	0.254	
C2L	0.480	0.400	
C2M	1.038	0.333	
C3H	0.735	0.063	
C3L	0.120	0.100	
C3M	0.260	0.083	
MH	0.180	0.150	
PC1	0.719	0.600	
PC2H	2.939	0.254	
PC2L	0.480	0.400	
PC2M	1.038	0.333	

Figure 9.25 Parameters of capacity curves for model building types with a high seismic design level.

9.3.9 Restoration Time

The damage state descriptions discussed in Section 9.3 provide a basis for establishing loss of function and repair time of facilities. A distinction should be made between loss of function and repair time. In this methodology, loss of function is defined as the time that a facility is not capable of conducting business. This, in general, will be shorter than repair time because businesses will rent alternative space while repairs and construction are being completed. Loss of function (restoration time) is estimated in the methodology only for essential facilities, transportation lifelines and utility lifelines.

Default restoration functions are provided with the methodology for essential facilities, transportation lifelines and utility lifelines. An example of a set of restoration functions is found in Figure 9.26. Restoration curves describe the fraction of facilities (or components in the case of lifelines) that are expected to be open or operational as a function of time following the earthquake. For example, looking at the curves shown in Figure 9.26, 10 days after the earthquake, about 20% of the facilities that were in the extensive damage state immediately after the earthquake and about 60% of the facilities that were in the moderate damage state immediately after the earthquake, are expected to be functional. Each curve is based on a Normal distribution with a mean and standard deviation. The parameters of the restoration functions are accessed through the **Analysis|Restoration Function** menu and can be viewed and modified in a window such as the one shown in Figure 9.27.

Typing in a new value and then clicking on the Close button will modify parameters for restoration curves. You will be asked to confirm that you want to save your changes. Restoration curves are based on data published in ATC-13. It is strongly recommended that you use the default parameters unless you have expertise in the development of restoration functions.

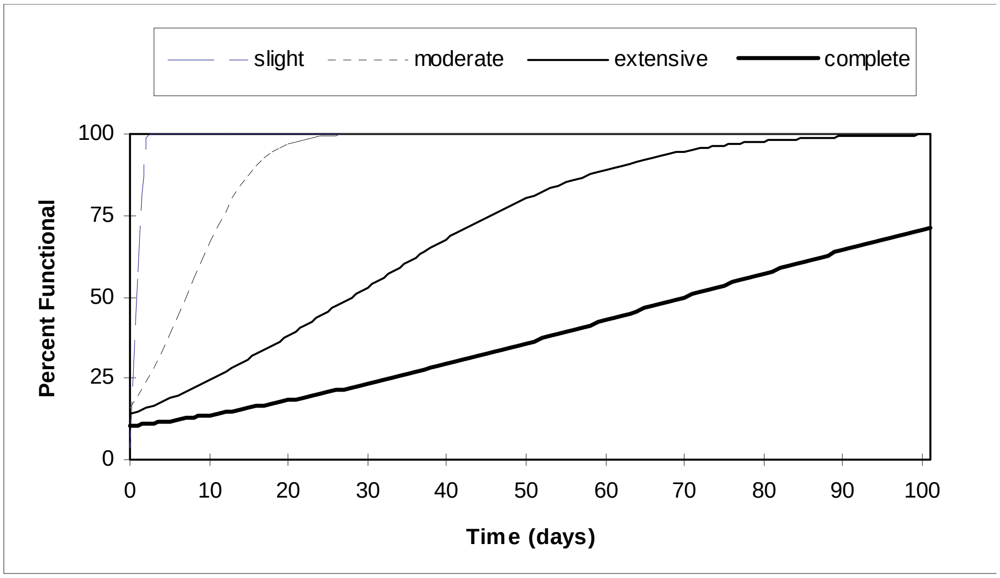
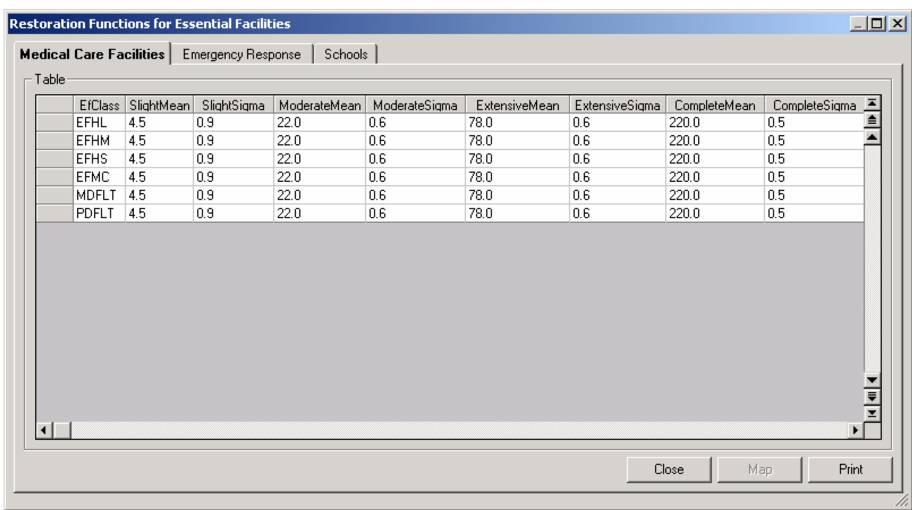


Figure 9.26 Restoration functions for a sample facility type.



EfClass	SlightMean	SlightSigma	ModerateMean	ModerateSigma	ExtensiveMean	ExtensiveSigma	CompleteMean	CompleteSigma
EFHL	4.5	0.9	22.0	0.6	78.0	0.6	220.0	0.5
EFHM	4.5	0.9	22.0	0.6	78.0	0.6	220.0	0.5
EFHS	4.5	0.9	22.0	0.6	78.0	0.6	220.0	0.5
EFMC	4.5	0.9	22.0	0.6	78.0	0.6	220.0	0.5
MDFLT	4.5	0.9	22.0	0.6	78.0	0.6	220.0	0.5
PDFLT	4.5	0.9	22.0	0.6	78.0	0.6	220.0	0.5

Figure 9.27 Reviewing and modifying restoration functions.

9.4 Induced Physical Damage Analysis

Potential indirect or induced physical damage due to ground shaking can be estimated. Induced damages include electrical fire starts, generation of debris, and inundation caused by dam or levee breaching in the aftermath of an earthquake. The **Induced Physical Damage** analysis module is accessible from the **HAZUS** menu bar **Analysis| Run**.

9.4.1 Inundation

In order to assess potential losses due to inundation, you must enter an inundation map under **Hazard|Data Maps** menu.

9.4.1.1 Tsunami

Damage, fatalities and fires from inundation due to tsunami can be significant. A tsunami is an ocean wave that is generated as a result of earthquake induced motion of the ocean floor. While the wave can be quite small (almost undetectable) in the open ocean, it can grow to great heights when it reaches land. Tsunamis have occurred in California, Alaska and Hawaii. Since models for estimation of losses from tsunamis are not well established, the methodology is limited to assessment of inundation potential unless an expert is involved.

The first step in the analysis is to identify whether a tsunami hazard exists. To accomplish this, the user must define the following:

1. location of the earthquake source (on-shore or off-shore event)
2. type of faulting expected (strike-slip, normal, reverse faulting)

If the earthquake source is on-shore, there is no tsunami hazard (see Figure 9.28). The same is true if an offshore event occurs that involves primarily strike-slip movement. Alternatively, if the earthquake occurs offshore and there is significant vertical offset that may occur, a tsunami hazard may exist. The focus of this methodology is the assessment of tsunami inundation for nearby seismic events only. While tsunamis can travel thousands of miles and cause damage at great distances from their sources, **HAZUS** does not consider tsunamis based on distant events well beyond the study region.

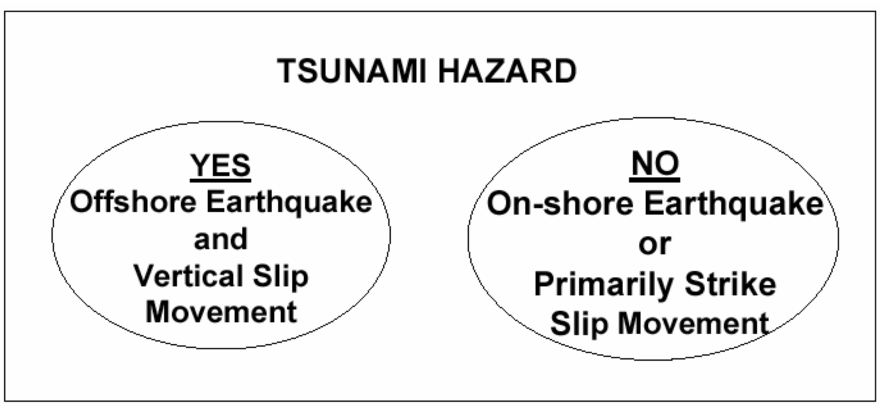


Figure 9.28 Evaluating the tsunami hazard.

If a tsunami hazard is found to exist, the next step is to identify the area that could be subjected to flooding. This is done with an inundation map. Development of an inundation map for a particular earthquake scenario requires the involvement of a hydrologist. In some cases, inundation maps based on previous studies exist and can be entered into **HAZUS** to overlay with building and lifeline inventories or population information. Converting maps into the **HAZUS** compatible format is discussed in Chapter 6 of this manual.

It should be noted that existing inundation studies must be examined to determine the origin of the seismic events (assumed or real) that generated the tsunami. If existing inundation studies are based only on distant events, the results of these assessments cannot be used as the basis to identify areas potentially vulnerable to tsunami-generated-inundation resulting from regional earthquakes. In addition, the user should determine the size and location of the scenario earthquake that was assumed when estimating the tsunami inundation. This will provide a basis to judge whether the existing inundation map conservatively or non-conservatively estimates the inundation that would be produced by the study earthquake.

9.4.1.2 Seiche

Seiches are waves in a lake or reservoir that are induced because of ground shaking. If the waves are large, damage can occur to facilities along the shore of the lake, or dams can be overtopped. Since models for estimation of losses from these hazards are not well established, **HAZUS** is limited to assessment of inundation potential unless an expert is involved.

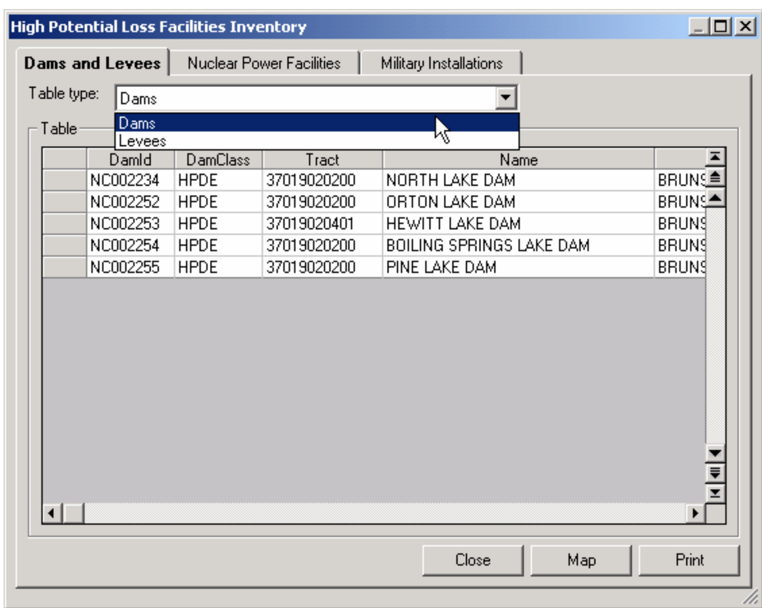


Figure 9.29 Default database of dams supplied with HAZUS.

The first step in this inundation analysis consists of developing an inventory of natural or man-made bodies of water where a seiche may be generated. The default database of dams can be used to identify the man-made bodies of water (see Appendix D, Section 5.1.5, and Figure 9.29). For the study region that has been defined, 5 dams are found in the default database. You must generate an inventory of natural water bodies in the study region, since no default database exists. The following criteria can be used to identify natural bodies of water that should be included in the assessment:

1. the lake volume must be greater than 500,000 acre-feet
2. there must be an existing population and/or property located in proximity to the lake shore that could be inundated

If these criteria are not met, the natural lake need not be considered in the study.

Once lakes or reservoirs with potential for generating seiches have been identified, the next step consists of locating and using existing seiche inundation maps to identify areas subject to flooding.

9.4.1.3 Dam or Levee Failure

In general, unless inundation maps already exist, you will limit your treatment of inundation due to dam failure to identifying those dams which have a high potential of causing damage. The database in its default form or augmented with additional data can be mapped to consider their locations. Users are responsible for developing their own inventory of levees, as no default levee inventory exists. If inundation maps exist, they can be input using the menu **Hazard|Data Maps**.

9.4.2 Analysis of Fire Following Earthquake

Fires following earthquakes can cause severe losses. For example, in the 1995 Kobe earthquake more than 10,000,000 square feet of buildings were lost to fires. Fires occurred as a result of ruptured gas pipelines. Fires spread rapidly because of the densely packed construction, narrow streets and the readily available fuel (wood frame structures, gas, and other flammable materials). The large amount of debris blocking the streets prevented fire fighters from accessing areas to fight the fires. Furthermore, broken water lines prevented fire fighters from suppressing the flames. Losses could have been significantly greater had there been strong winds to fuel the fire. The losses from fire can sometimes outweigh the total losses from the direct damage caused by the earthquake, such as collapse of buildings and disruption of lifelines.

Many factors affect the severity of the fires following an earthquake, including but not limited to: ignition sources, types and density of fuel, wind conditions, the presence of ground failure, functionality of water systems, and the ability of fire fighters to suppress the fires. It should be recognized that a complete fire following earthquake (FFE) model requires extensive input with respect to the level of readiness of local fire departments and the types and availability (functionality) of water systems. To reduce the input requirements and to account for simplifications that are being made in the lifeline module, the fire following earthquake model presented in this methodology is somewhat simplified. In particular the model makes simplifying assumptions about the availability of water and fire trucks in modeling fire suppression.

The FFE module performs a series of simulations of fire spread and bases estimates of burned area on the average of the results the simulations:

9.4.2.1 Parameters for the Fire Following Earthquake Module

To run the FFE analysis module you have to adjust the parameters shown in Figure 9.30. Access this window from the **HAZUS** menu bar **Analysis|Parameters|Fire Following**. Guidance for editing the parameters follows in the next sections.

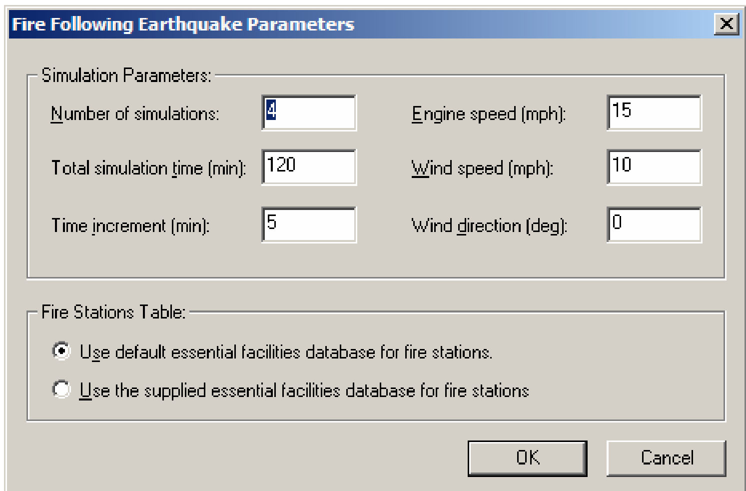


Figure 9.30 Parameter window for fire following earthquake module.

9.4.2.2 Number of Simulations

Since estimates of the burned area are based upon averaging results of multiple simulations of fire spread, you can perform more simulations to improve the reliability of the estimates of burned area. The number of ignitions is based upon PGA and the square footage of inventory, and thus the number of simulations does not affect it. You can specify up to 99 simulations, but 6 to 10 simulations should be sufficient. This module takes some time to run, increasing the number of simulations, increases the run time.

9.4.2.3 Total Simulation Time and Time Increment

The total simulation time is an indicator of how long after the earthquake you want to look at the fire damage. For example if you specify 120 minutes, you will be provided with estimates of the burned area two hours after the occurrence of the earthquake. You can specify a maximum of 9999 minutes. The time increment is used to specify the time periods at which the program should sample and update the simulation. For example if you specify a time increment of 15 minutes, the program will sample at 15, 30, 45 and so on, minutes after the earthquake. You should provide a time increment of 1 to 15 minutes to get sufficiently accurate results.

9.4.2.4 Engine Speed

Engine speed is used in the suppression portion of the simulation. The faster the engines can access the sites of fires, the more quickly fires can be suppressed. Fire engines are slowed down by damaged transportation systems, damaged water or gas pipes or by debris in the road. You may specify a maximum speed of 60 miles per hour.

9.4.2.5 Wind Speed and Direction

High wind speeds will serve to fuel the fire. A calm day (zero wind) will produce the lowest estimates of burned area. You may specify a maximum wind speed of 100 miles per hour. The direction of wind is measured clockwise in degrees (0 to 360) with zero being due north.

9.4.3 Hazardous Materials Analysis Option

Hazardous materials are those chemicals, reagents or substances that exhibit physical or health hazards. Hazardous materials may be in a usable or waste state. Hazardous materials releases can also lead to fires. With specific reference to earthquake-caused hazardous materials incidents, the data thus far indicate that there have been no human casualties. The consequences of these incidents have been fires and contamination of the environment, and have led to economic impacts because of the response and clean-up requirements.

The hazardous materials analysis option has not been activated. A default database listing the types of hazardous materials in your region and locations of sites where hazardous materials are stored can be accessed by using the **Inventory|Hazardous Materials** menu (see Figure 9.31). The sites are mappable within the study region. Additional data can be added using the steps outlined in Section 6.2.

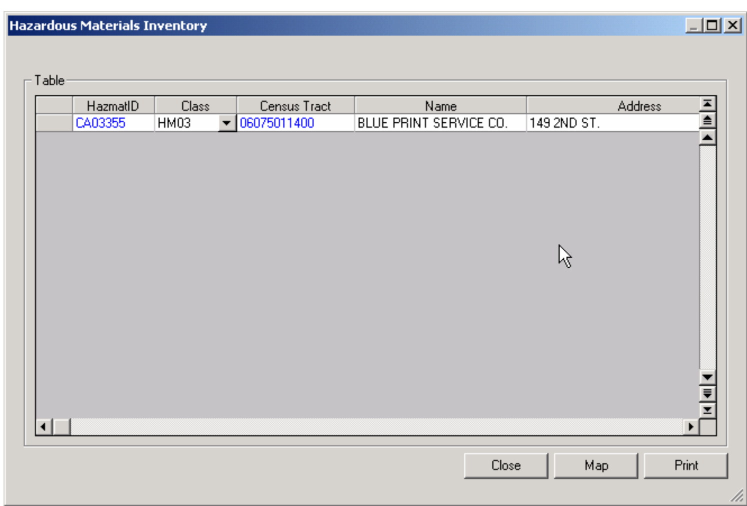


Figure 9.31 Hazardous materials inventory.

9.4.4 Debris Estimates

Very little research has been done to determine the amount of debris generated from earthquakes and other natural disasters. However, anecdotal evidence suggests that removal of debris can be a significant part of the clean up process and, as such, can be costly for a municipality. After Hurricane Hugo, the City of Charleston disposed of so much debris that 17 years were removed from the life of its landfill. Debris can also hinder emergency operations immediately after an earthquake if it is blocking streets, sidewalks or doorways. Where collapses or partial collapses of buildings occur, rescue of victims can be difficult if the walls or floors of the structure come down essentially intact. A short discussion of heavy debris generation and victim extrication can be found in FEMA publication 158 (1988).

9.4.4.1 Types and Sources of Debris

A major source of debris will be structures that have been completely damaged or have collapsed. Debris will include building contents as well as structural and non-structural elements. Completely damaged buildings may still be standing, but the cost of repair could be so high, that these buildings will be torn down and rebuilt. However, even buildings that do not suffer extensive damage can be sources of debris. If damage to the building is slight or moderate, the majority of the damage may be to non-structural elements or contents inside the building. Examples of non-structural debris are suspended ceilings, light fixtures, and partition walls made of plaster or hollow clay tile. In addition, extensive damage could occur to contents of the building such as shelving, equipment, and inventory.

Different types of buildings will generate different types of debris. Unreinforced masonry structures will tend to generate piles of bricks. The bricks result from a collapse of a wall or from damage to some non-structural element such as an unbraced parapet. In single-family dwellings of wood construction, chimneys may separate from the rest of the structure causing them to be torn down and rebuilt. Many steel and concrete frame buildings that were built in the first half of the century have exterior cladding made of brick or terra cotta that may spell off when subjected to earthquake motion. Non-ductile concrete buildings may collapse in a pancake fashion, resulting in a stack of concrete slabs that are not broken up. In a tilt-up building, concrete wall panels, which are usually on the exterior of the structure, may fall outward remaining essentially intact. When the walls fall, the roof (typically of wood or light metal deck) will also collapse. In modern high rise structures, precast panels used for exterior cladding may come loose and fall to the ground or windows may break. Should a steel structure collapse, as one did in Mexico City in 1985, large pieces of twisted steel would result.

In reviewing the types of debris that are generated from an earthquake, the debris can be divided into two types:

- Debris Type 1 Brick, wood and other debris
- Debris Type 2 Wrecked reinforced concrete and steel members

The first type of debris includes everything except wrecked reinforced concrete and steel members. It would include glass, furniture, equipment, and plaster walls, as well as brick and wood. The difference in these two types of debris is that Type 1 can be moved and broken up with a bulldozer or hand held tools. Type 2 would require special treatment to break up the long steel members or the large pieces of concrete before they could be transported. It is likely cranes and other heavy equipment would be needed.

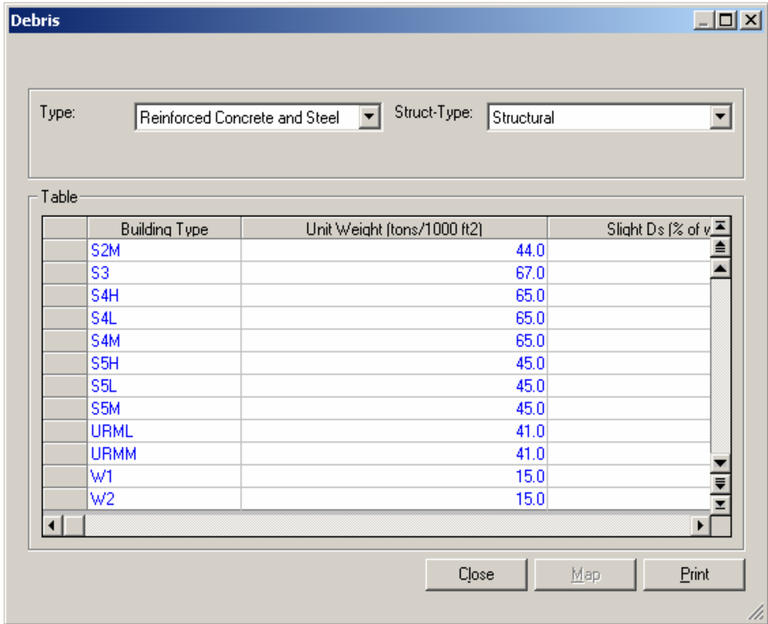
While estimates of debris could include debris due to collapsed bridges and overpasses as well as debris due to buildings, **HAZUS** ignores debris generated from collapsed bridges. Due to the simplifications that are introduced in the modeling of transportation systems, and in particular the lack of inventory detail regarding dimensions of individual bridges, any estimation of quantities of bridge debris would contain large uncertainties and might be misleading.

9.4.4.2 Debris Parameters

The debris module will provide an estimate for each census tract of the amount (tons) of debris of each type that will be generated. Estimates of debris are based upon the structural and non-structural damage states that are output from the building damage module. Square footage of each model building type also is required, but is available from the building inventory module. Two additional sets of data are required to estimate the amount of debris that is generated from damaged buildings. These are:

- Weight in tons of structural and non-structural elements per square foot of floor area for each model building type
- The amount of debris generated for each structural and non-structural damage state in terms of percent of weight of elements

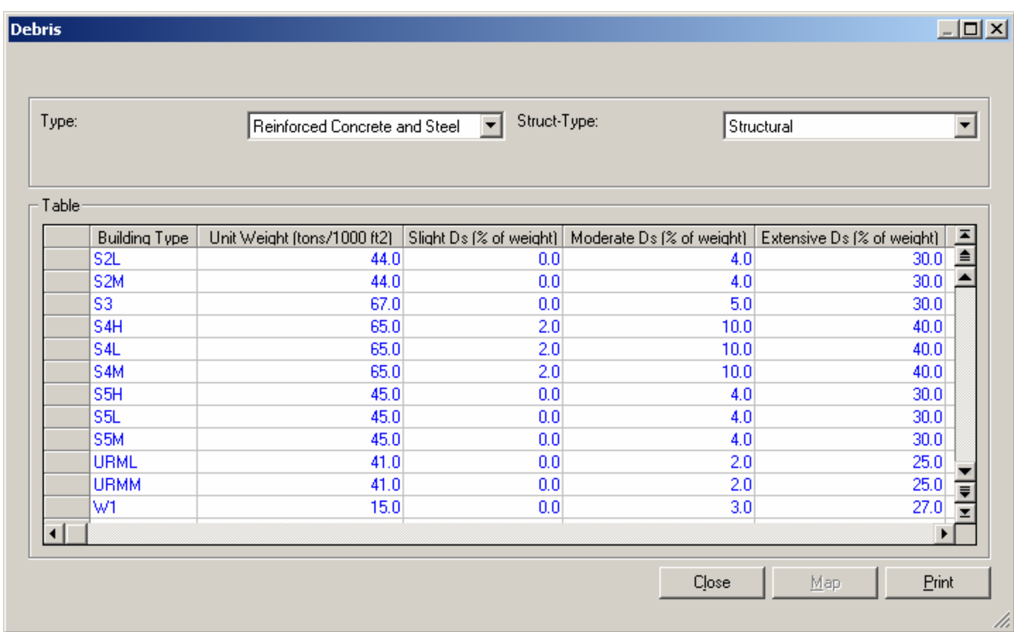
Estimates of debris can be generated using the default data supplied with **HAZUS**. Figure 9.32 shows the default values of debris weight for each model building type. Clicking on the **Analysis|Parameters|Debris** menu accesses this window. For each model building type there are two unit weight tables. The first table includes Type 1 materials such as brick, wood and other debris, while the second is limited to the Type 2 materials such as reinforced concrete and steel. Both tables use the number of tons of material per 1000 square feet of building area. For example, Figure 9.32 shows that for each 1000 square feet of W1 construction there are 15 tons of Type 1 structural material . These values are based upon assumptions of “typical buildings”. These values can be modified to more accurately reflect the buildings in your area if such data is available.



Building Type	Unit Weight (tons/1000 ft2)	Slight Ds (% of v
S2M	44.0	
S3	67.0	
S4H	65.0	
S4L	65.0	
S4M	65.0	
S5H	45.0	
S5L	45.0	
S5M	45.0	
URML	41.0	
URMM	41.0	
W1	15.0	
W2	15.0	

Figure 9.32 Weight of structural and non-structural elements for debris Type 1 in terms of tons per 1000 square feet of building area.

Default values are also provided for Type 1 and Type 2 debris in terms of percentage of weight of elements and the damage state. As shown in Figure 9.33, for low rise steel braced frames (S2L) one can expect to remove debris equal to 30% of the weight of brick and wood if the damage state is extensive. These default values are based upon observations of damage in past earthquakes. These values can be modified to more accurately reflect the buildings in your area if such data is available.



Building Type	Unit Weight (tons/1000 ft2)	Slight Ds (% of weight)	Moderate Ds (% of weight)	Extensive Ds (% of weight)
S2L	44.0	0.0	4.0	30.0
S2M	44.0	0.0	4.0	30.0
S3	67.0	0.0	5.0	30.0
S4H	65.0	2.0	10.0	40.0
S4L	65.0	2.0	10.0	40.0
S4M	65.0	2.0	10.0	40.0
S5H	45.0	0.0	4.0	30.0
S5L	45.0	0.0	4.0	30.0
S5M	45.0	0.0	4.0	30.0
URML	41.0	0.0	2.0	25.0
URMM	41.0	0.0	2.0	25.0
W1	15.0	0.0	3.0	27.0

Figure 9.33 Debris generated in terms of percent of weight of elements for each model building type and each structural and non-structural damage state.

9.5 Running the Direct Social and Economic Loss Modules

The **Direct social and economic loss** modules are used for estimating casualties, displaced households due to loss of housing habitability, short-term shelter needs, and direct economic impacts resulting from damage to buildings and lifelines. Clicking on the **Direct Social Losses** option in the window shown in Figure 9.34 will cause the following menu to appear.

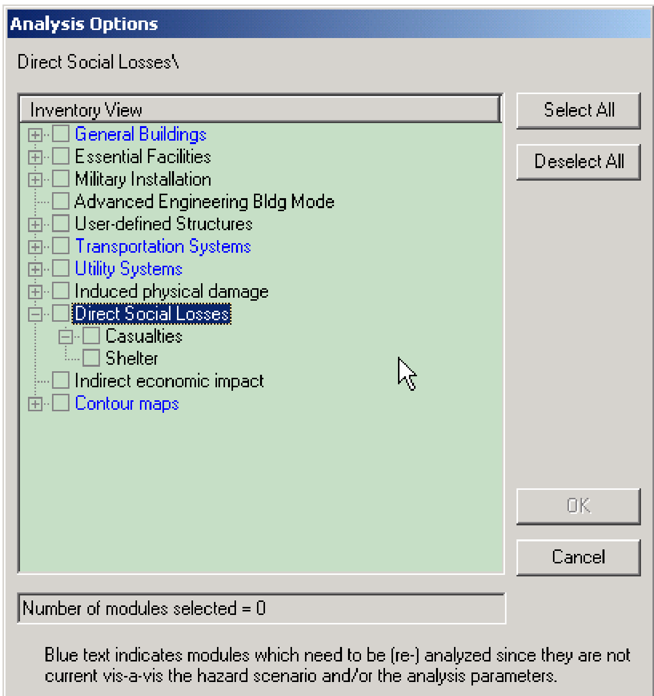


Figure 9.34 Direct economic losses

The direct economic loss option can be selected for each inventory type (general buildings, essential facilities, etc.) Select the types of analyses you wish to run, click on the **Close** button and then click on the **OK** button shown in the window in Figure 9.34. These social and economic analyses can only be run if the **direct physical damage** module is either run simultaneously, or if it has previously been run.

9.5.1 Casualty Estimates

The casualty module calculates the following estimates for each census tract at three times of day (2 AM, 2 PM and 5 PM):

- Single family dwelling (RES1) casualties (Severity 1, 2, 3 and 4)
- Residential (other than RES1) casualties (Severity 1, 2, 3 and 4)
- Commercial casualties (Severity 1, 2, 3 and 4)
- Industrial casualties (Severity 1, 2, 3 and 4)
- Education casualties (Severity 1, 2, 3 and 4)
- Hotel casualties (Severity 1, 2, 3 and 4)
- Commuting casualties (Severity 1, 2, 3 and 4)
- Total casualties (Severity 1, 2, 3 and 4)

The following inputs are needed to obtain estimates of casualties:

- Population distribution by census tract
- Population distribution within census tract
- Building stock inventory
- Damage state probabilities
- Time of day of estimate (2 AM, 2 PM or 5 PM)
- Casualty rates by damage state of model building
- Collapse rates due to collapse of model building/bridge type
- Number of commuters on or under bridges in the census tract

All of this information has already been provided by other modules or is available as a default.

9.5.1.1 Injury Classification Scale

The output from the module consists of a casualty breakdown by injury severity, defined by a four-tier injury severity scale (Coburn, 1992; Cheu, 1994). Table 9.8 defines the injury classification scale used in **HAZUS**.

Table 9.8 Injury Classification Scale

Injury Severity	Injury Description
Severity 1	Injuries requiring basic medical aid without requiring hospitalization
Severity 2	Injuries requiring a greater degree of medical care and hospitalization, but not expected to progress to a life threatening status
Severity 3	Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. The majority of these injuries are a result of structural collapse and subsequent collapse or impairment of the occupants.
Severity 4	Instantaneously killed or mortally injured

Other, more elaborate casualty scales exist. They are based on quantifiable medical parameters such as medical injury severity scores, coded physiologic variables, etc. The selected four-tier injury scale used in **HAZUS** is a compromise between the demands of the medical community (in order to plan their response) and the ability of the engineering community to provide the required data. For example, medical professionals would like to have the classification in terms of "Injuries/Illnesses" to account for worsened medical conditions caused by an earthquake (e.g., heart attack). However, currently available casualty assessment methodologies do not allow for a finer resolution in the casualty scale definition.

9.5.1.2 Casualty Rates

In order to estimate the number and severity of the casualties, statistics from previous earthquakes were analyzed to develop relationships that reflect the distribution of injuries one would expect to see resulting from building and bridge damage. These casualty rates were developed for each casualty severity and are multiplied by the exposed population to estimate the number of casualties. An example of a calculation of casualties follows:

Severity 1 casualty rate for low rise Unreinforced masonry buildings (URML) with slight structural damage = 1 in 2,000

Number of people in the study region who were in slightly damaged URML buildings = 50,000

Severity 1 casualties = 50,000∗1/2,000 = 25 people

The following default casualty rates are defined by **HAZUS** and can be found in the *Technical Manual*:

- Casualty rates by model building type for slight structural damage
- Casualty rates by model building type for moderate structural damage
- Casualty rates by model building type for extensive structural damage
- Casualty rates by model building and bridge types for complete structural damage with no collapse
- Casualty rates after collapse by model building type.

Note that a separate set of casualty rates was developed for entrapped victims, and that collapse is only considered in the case of complete structural damage. It is assumed that in the cases of slight, moderate and extensive structural damage, collapses do not occur and building collapse is unlikely. Casualty rates for both buildings and bridges can be viewed and modified in the window shown in Figure 9.35. Selecting the Analysis|Parameters|Casualties menu accesses this window. These default casualty rates can be modified if improved information is available. To modify values, type in the new numbers and click on the **Close** button. You will be asked to confirm your changes.

It should be noted that complete data does not exist for all model building types and injury severity. Missing data were inferred from reviewing previous studies. Collection of better and more complete casualty statistics would involve a major research study.

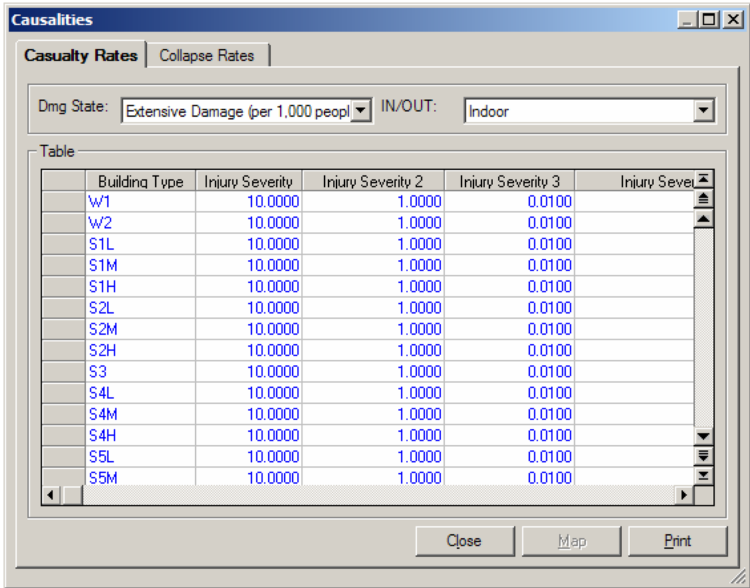
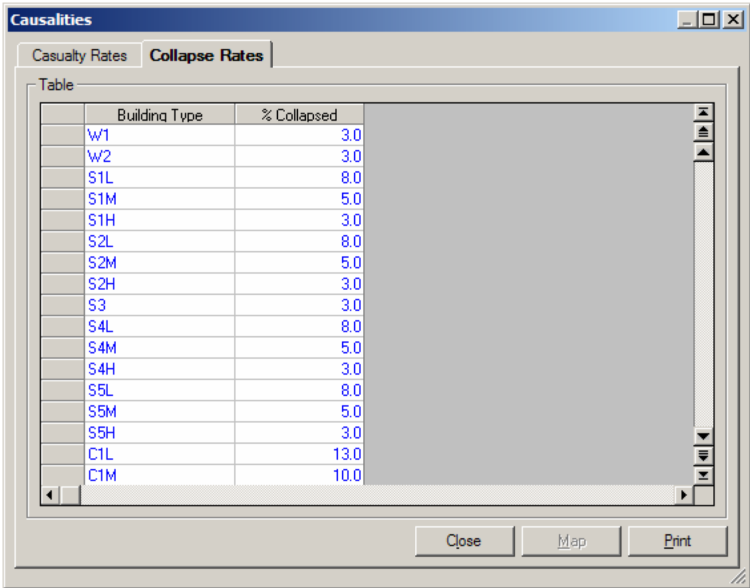


Figure 9.35 Casualty rates in number of casualties per 1,000 occupants by model building type for the slight structural damage state (indoors).

9.5.1.3 Collapse Rates

When collapses or partial collapses occur, individuals may become trapped under fallen debris or trapped in air pockets amongst the rubble. Casualties tend to be more severe in these cases, and as was discussed in Section 9.5 a separate set of casualty rates was developed for entrapped victims. It should be noted that building collapse rates (in percent of occupants) are developed only for the complete damage state. This is because it is assumed that no collapses or partial collapses occur in the slight, moderate or extensive damage states and collapse in these cases is unlikely. Collapse rates by model building type can be found in the *Technical Manual*. They can also be viewed within **HAZUS** as is shown in Figure 9.36. This window is accessed from the **Analysis|Parameters|Casualties** menu. To modify values, type in the new numbers and click on the **Close** button. You will be asked to confirm your changes.



Building Type	% Collapsed
W1	3.0
W2	3.0
S1L	8.0
S1M	5.0
S1H	3.0
S2L	8.0
S2M	5.0
S2H	3.0
S3	3.0
S4L	8.0
S4M	5.0
S4H	3.0
S5L	8.0
S5M	5.0
S5H	3.0
C1L	13.0
C1M	10.0

Figure 9.36 Collapse rates for buildings as displayed in HAZUS.

9.5.2 Estimates of Displaced Households Due to Loss of Housing Habitability and Short-Term Shelter Needs

Earthquakes can cause loss of function or habitability of buildings that contain housing units resulting in predictable numbers of displaced households. These households will need alternative short-term shelter from family, friends, or public shelters provided by relief organizations such as the Red Cross and Salvation Army. For units where repair takes longer than a few weeks, long-term alternative housing can be achieved through importation of mobile homes, a reduction in vacant units, net emigration from the impacted area, and eventually by the repair or reconstruction of new public and private housing. While the number of people seeking short-term public shelter is of great concern to emergency response organizations, the longer-term impacts on the housing stock are of great concern to local governments. The shelter module provides two estimates:

- The total number of displaced households (due to loss of habitability)
- The number of people requiring short-term shelter

Loss of habitability is calculated directly from damage to the residential occupancy inventory and from loss of water and power. The methodology for calculating short-term shelter requirements recognizes that only a portion of those displaced from their homes will seek public shelter, and some will seek shelter even though their residence may have little, if any, damage.

Households also may be displaced as a result of fire following earthquake, inundation (or the threat of inundation) due to dam failure, and by significant hazardous waste releases. This module does not specifically deal with these issues, but an approximate estimate of displacement due to fire or inundation can be obtained by multiplying the residential inventory in affected census tracts by the areas of fire damage or inundation derived from those modules. No methodology for calculations of damage or loss due to hazardous materials is provided, and the user is confined to identifying locations of sites where hazardous materials are stored. If the particular characteristics of the study region give cause for concern about the possibility of loss of housing from fire, dam failure, or hazardous materials release, it would be advisable to initiate specific in-depth studies directed towards the problem.

All households living in uninhabitable dwellings will seek alternative shelter. Many will stay with friends and relatives or in the family car. Others will stay in hotels. Some will stay in public shelters provided by the Red Cross or others. **HAZUS** estimates the number of displaced persons seeking public shelter. In addition, observations from past disasters show that approximately 80% of the pre-disaster homeless will seek public shelter. Finally, data from Northridge indicate that approximately one-third of those in public shelters came from residences with no or insignificant structural damage. Depending on the degree to which infrastructure damage is incorporated into the number of displaced households, that number could be increased by up to 50% to account for "perceived" structural damage as well as lack of water and power.

9.5.2.1 Development of Input for Displaced Households

The following inputs are required to compute the number of uninhabitable dwelling units and the number of displaced households.

- Fraction of dwelling units likely to be vacated if damaged
- Probability that the residential units are without power and/or water immediately after the earthquake.
- Percentage of households affected by utility outages likely to seek alternative shelter.

9.5.2.1.1 Fraction of Dwelling Units Likely to be vacated if damaged:

The number of uninhabitable dwelling units is not only a function of the amount of structural damage but it is also a function of the number of damaged units that are perceived to be uninhabitable by their occupants. All dwelling units located in buildings that are in the complete damage state are considered to be uninhabitable. In addition, dwelling units that are in moderately or extensively damaged multi-family structures can also be uninhabitable due to the fact that renters perceive some moderately damaged and most extensively damaged rental property as uninhabitable. On the other hand, those living in single-family homes are much more likely to tolerate damage and continue to live in their homes. Therefore weighting factors have been developed that describe the fraction of dwellings likely be vacated if they are damaged. These default weighting factors can be viewed and modified as shown in Figure 9.37. To access this window use the **Analysis|Parameters| Shelter** menu.

In this table, the subscript “SF” corresponds to single family dwellings and the subscript MF corresponds to multi-family dwellings. The subscripts M, E, and C correspond to moderate, extensive and complete damage states, respectively. For example, based on these defaults, it is assumed that 90% of multi-family dwellings will be vacated if they are in the extensive damage state (see w_{MFE}). Discussion of how the defaults were developed can be found in the *Technical Manual*.

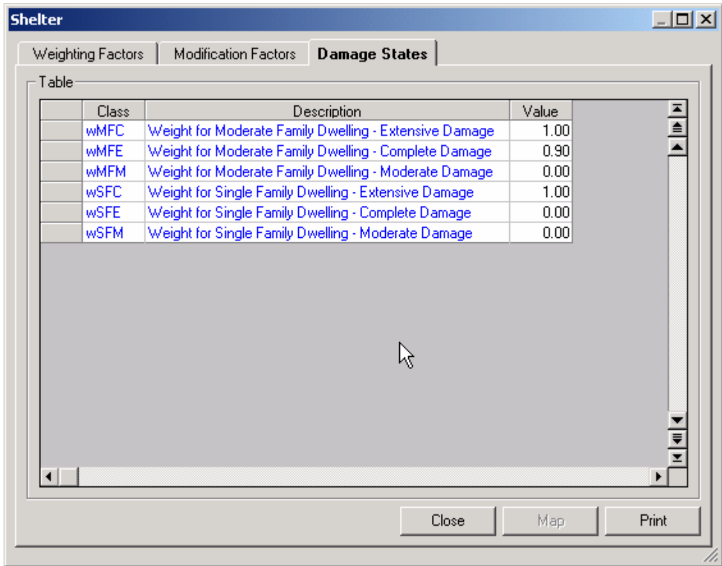


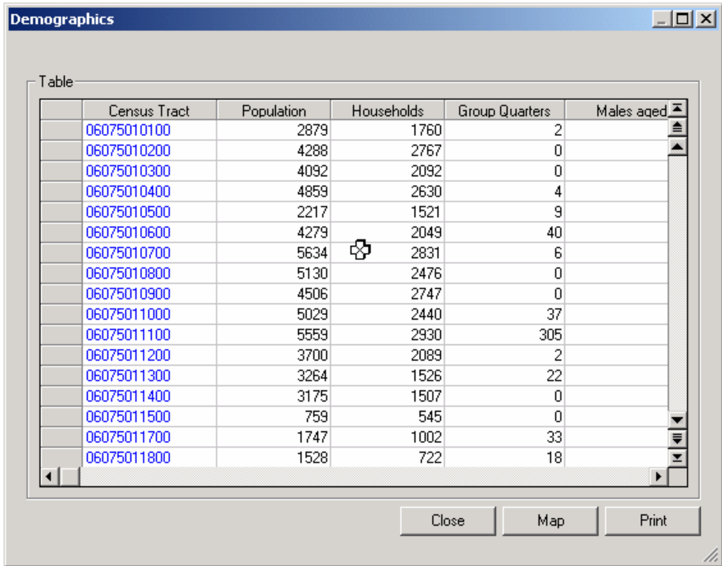
Figure 9.37 Default values for the fraction of dwelling units likely to be vacated if damaged.

9.5.2.2 Development of Input for Shelter Needs

The number of displaced households is combined with the following information to estimate shelter needs:

- Number of people in the census tract
- Number of households in census tract
- Income breakdown of households in census tract
- Ethnicity of households in census tract
- Percentage of homeowners and renters in the census tract
- Age breakdown of households in census tract

All of this information is provided in the default census database. The default census database can be viewed, modified and mapped in the inventory module as shown in Figure 9.38. Figure 9.39 is a map of households with incomes less than $10,000. Highlighting the Income column in the census database and clicking on the **Map** button accomplished this. Note that to see this column you would need to click on the right arrow at the bottom of Figure 9.38.



Demographics

Table

Census Tract	Population	Households	Group Quarters	Males aged
06075010100	2879	1760	2	
06075010200	4288	2767	0	
06075010300	4092	2092	0	
06075010400	4859	2630	4	
06075010500	2217	1521	9	
06075010600	4279	2049	40	
06075010700	5634	2831	6	
06075010800	5130	2476	0	
06075010900	4506	2747	0	
06075011000	5029	2440	37	
06075011100	5559	2930	305	
06075011200	3700	2089	2	
06075011300	3264	1526	22	
06075011400	3175	1507	0	
06075011500	759	545	0	
06075011700	1747	1002	33	
06075011800	1528	722	18	

Close Map Print

Figure 9.38 Demographics data supplied in HAZUS.

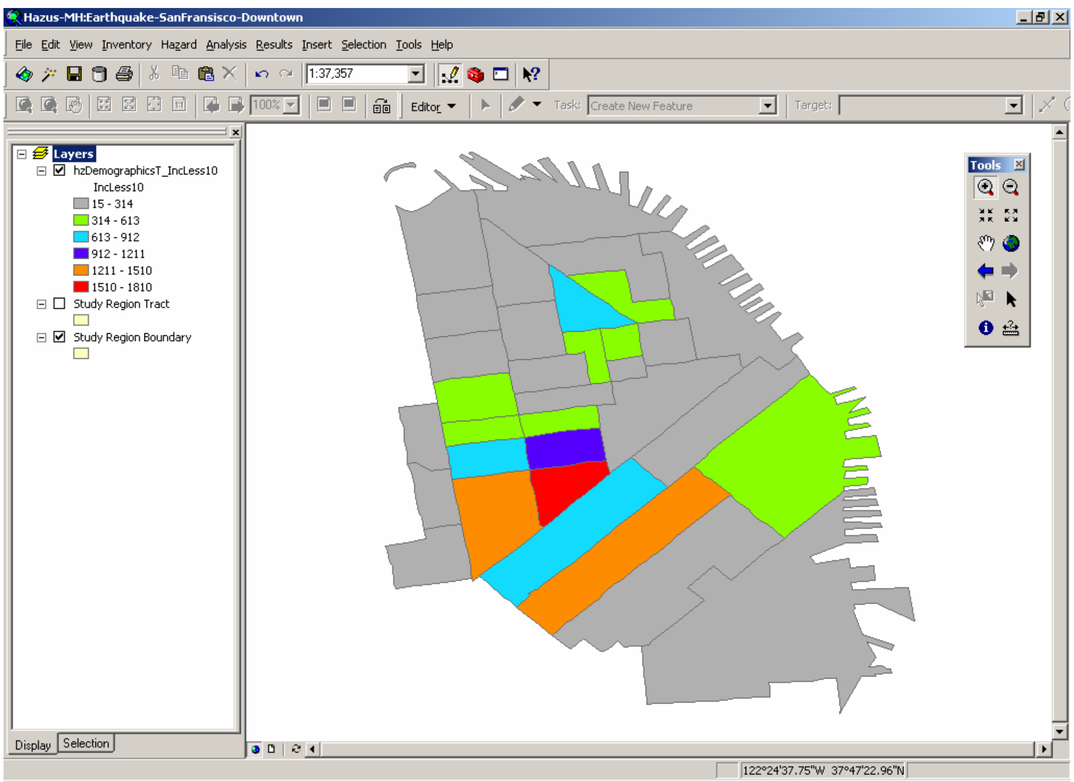


Figure 9.39 Map of households with incomes less than $10,000

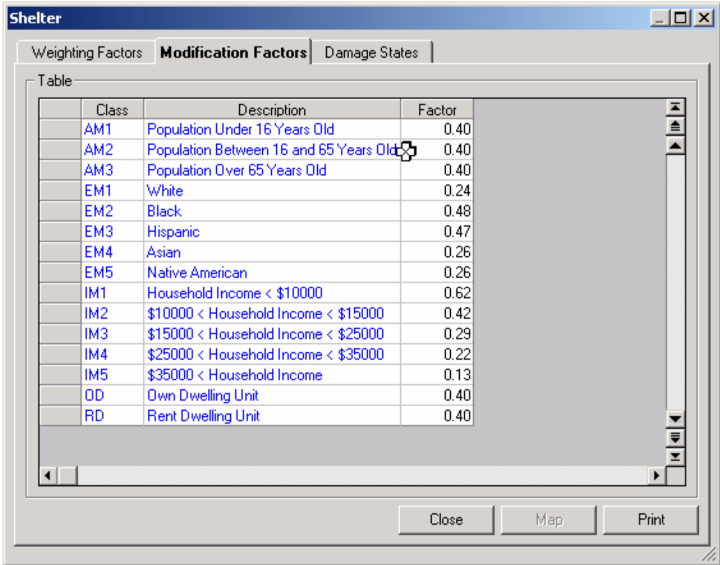
Assumptions of the methodology are that the number of people who require short-term housing is a function of income, ethnicity, ownership and age. Based on experience in past disasters, including both hurricanes and earthquakes, those seeking shelter typically have very low incomes, and therefore have fewer options. In addition, they tend to have young children or are over 65. Finally, even given similar incomes, Hispanic populations from Central America and Mexico tend to be more concerned about reoccupying buildings than other groups. This tendency appears to be because of the fear of collapsed buildings instilled from past disastrous earthquakes.

To account for these trends, factors have been developed to represent the fraction of households in each category likely to seek public shelter if their dwellings become uninhabitable. The default values of these factors as shown in Table 9.9 are based upon data from the Northridge earthquake combined with expert opinion (see the *Technical Manual* for more information). From this table you can interpret that 62% of households with incomes less than $10,000 whose dwellings have become uninhabitable will seek public shelter.

Table 9.9 Fraction of Households Likely to Seek Public Shelter

Household Description	Default
Income	
Household Income < $10,000	0.62
$10,000 < Household Income < $15,000	0.42
$15,000 < Household Income < $25,000	0.29
$25,000 < Household Income < $35,000	0.22
$35,000 < Household Income	0.13
Ethnicity	
White	0.24
Black	0.48
Hispanic	0.47
Asian	0.26
Native American	0.26
Ownership	
Own Dwelling Unit	0.40
Rent Dwelling Unit	0.40
Age	
Population Under 16 Years Old	0.40
Population Between 16 and 65 Years Old	0.40
Population Over 65 Years Old	0.40

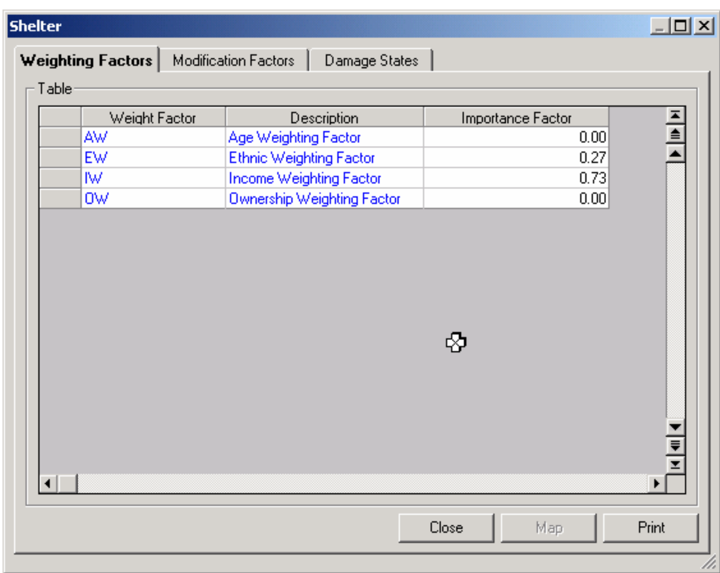
The factors in Table 9.9 can be viewed and modified in the **Shelter Parameters** window as shown in Figure 9.40. The **Income**, **Ethnicity**, **Ownership** and **Age** buttons can be used to view the various tables.



Class	Description	Factor
AM1	Population Under 16 Years Old	0.40
AM2	Population Between 16 and 65 Years Old	0.40
AM3	Population Over 65 Years Old	0.40
EM1	White	0.24
EM2	Black	0.48
EM3	Hispanic	0.47
EM4	Asian	0.26
EM5	Native American	0.26
IM1	Household Income < $10000	0.62
IM2	$10000 < Household Income < $15000	0.42
IM3	$15000 < Household Income < $25000	0.29
IM4	$25000 < Household Income < $35000	0.22
IM5	$35000 < Household Income	0.13
OD	Own Dwelling Unit	0.40
RD	Rent Dwelling Unit	0.40

Figure 9.40 Fraction of households likely to seek public shelter as a function of household income.

You have the option to weight the importance of the four factors that affect the fraction of households seeking public shelter: income, ethnicity, ownership and age. The **importance factors** must sum to one. Defaults of the importance factors are shown in Figure 9.41. The default importance factors indicate that no weight will be put on ownership or age, and income will be weighted almost 3 times as much as ethnicity. If you wish to give all classes equal importance, then the factors should all be 0.25.



Weight Factor	Description	Importance Factor
AW	Age Weighting Factor	0.00
EW	Ethnic Weighting Factor	0.27
IW	Income Weighting Factor	0.73
OW	Ownership Weighting Factor	0.00

Figure 9.41 Importance Factors for determining shelter needs.

9.5.3 Direct Economic Loss

Estimates of damage to the built environment are converted to dollar loss in this module. Beyond economic losses, whose dollar value can be estimated from the extent of building and lifeline damage, there are a number of common socioeconomic impacts from earthquakes that, though their impact is not readily quantifiable, may represent important earthquake effects. These impacts may vary, depending on socioeconomic aspects of the population at risk and the particular physical topography and layout of the affected region. These are impacts such as:

Psychological and emotional trauma that may affect a variety of populations, such as school children, ethnic groups, recent immigrants, the elderly and the infirm. These effects may influence post-earthquake behavior, for example in the choice of or need for shelter, and require the deployment of large-scale psychological and counseling services. Some of these effects may be of long duration, and may affect children's behavior and adult family and work efficiency.

- Changes in work and leisure travel time patterns caused by bridge or freeway failures. Large increases in travel time may result in hardship and family stress. At a large scale, they may affect the regional economy.
- Changes in community and family structure caused by large-scale housing losses and consequent relocation and demolition.

This methodology does not attempt to estimate such effects. If the user of the methodology is interested in the possible impact of such effects on the community or region under study, it is recommended that they begin by consulting bibliographic sources to obtain an understanding of the possible importance of these impacts for the area of study. A useful discussion of many of these impacts can be found in "The Loma Prieta, California, Earthquake of October 17, 1989 - Public Response" (Bolton, 1993). This publication has bibliographic references that may be useful for further study.

9.5.3.1 Types of Direct Economic Loss

Direct economic losses begin with the cost of repair and replacement of damaged or destroyed buildings. However, building damage will result in a number of consequential losses that, in **HAZUS**, are defined as direct. Thus, building-related direct economic losses (which are all expressed in dollars) comprise two groups. The first group consists of losses that are directly derived from building damage:

- Cost of repair and replacement of damaged and destroyed buildings
- Costs of damage to building contents
- Losses of building inventory (contents related to business activities)

The second group consists of losses that are related to the length of time the facility is non-operational (or the immediate economic consequences of damage):

- Relocation expenses (for businesses and institutions)
- Capital-related income losses (a measure of the loss of productivity, services or sales)
- Wage losses (consistent with income loss)
- Rental income losses (to building owners)

Damage to lifeline and transportation systems causes direct economic losses analogous to those caused by building damage. In **HAZUS**, direct economic loss for lifelines and transportation systems are limited to the cost of repairing damage to the systems, and estimates of elapsed time for their restoration. No attempt is made to estimate losses due to interruption of customer service or alternative supply services.

Dollar losses due to inundation are not explicitly addressed. **HAZUS** estimates the area of inundation and then relates this estimate to the quantity of building stock in the affected census tracts. This estimate in turn can be converted to a dollar value.

In a similar manner, a value for building losses from fire can be estimated by relating the area of fire spread to the volume of construction and construction cost. In both cases, the nature of damage state (which vary from those due to ground shaking damage) are not developed and estimates of dollar loss from these causes should be regarded as very broad estimates. In addition, one must be careful that double counting does not occur when evaluating damages due earthquake, inundation, and fire (for example a collapsed building that burns to the ground in a flood zone).

No methodology is provided for estimating losses due to release of hazardous materials.

9.5.3.2 Development of Input for Building Losses

A great deal of default economic data is supplied with **HAZUS**, as follows:

- Structural repair costs (%) for each of the damage states, model building types and occupancies
- Non-structural repair costs (%) for all occupancies (both acceleration sensitive and drift sensitive damage)
- Contents damage as a function of damage state
- Annual gross sales or production in $ per square foot for agricultural, commercial and industrial occupancies
- Business inventory as a percentage of gross annual sales for agricultural, commercial and industrial occupancies
- Business inventory damage as a function of damage state for agricultural, commercial and industrial occupancies
- Building cleanup and repair time in days as a function of damage state and occupancy
- Parameters used to estimate facility loss of function for each damage state and occupancy
- Rental costs
- Disruption costs
- Percent of buildings that are owner occupied for each occupancy class
- Capital-related income and wage income in $/day per square foot for each occupancy

These data are described in detail in the *Technical Manual*. With the exception of repair costs, the default data represent typical values for the United States and thus no regional variations are included. You will want to review the default data very carefully and modify the data to best represent the characteristics of your region. The default data can be viewed and modified from within **HAZUS**. The window that is used to view and modify economic default data is shown in Figure 9.42. This window is accessed from the **Analysis|Parameters|Buildings-Economic** menu.

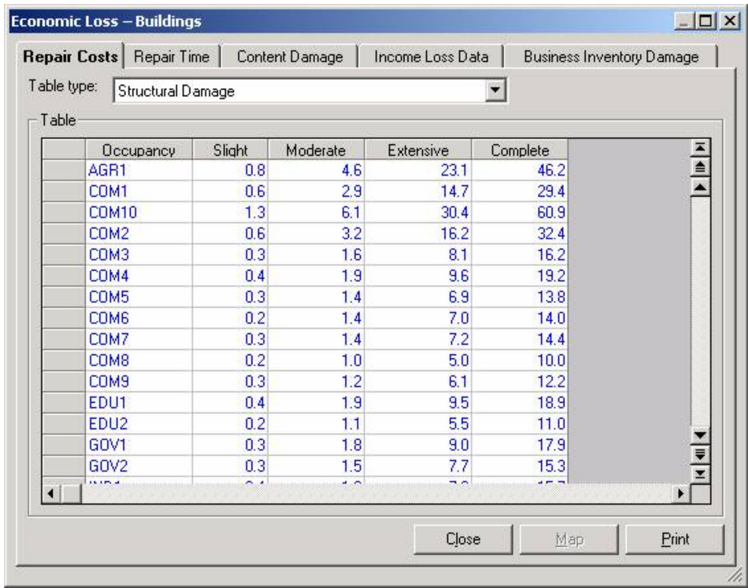


Figure 9.42 Economic data for estimating building repair costs, contents and business inventory losses, lost income and relocation costs.

9.5.3.2.1 Replacement Costs:

The replacement costs (damage state = complete) were derived from Means Square Foot Costs 2002, for Residential, Commercial, Industrial, and Institutional buildings (Jackson, 1994). The Means publication is a nationally accepted reference on building construction costs, which is published annually. This publication provides cost information for a number of low-rise residential model buildings, and for 70 other residential, commercial, institutional and industrial buildings. These are presented in a format that shows typical costs for each model building, showing variations by size of building, type of building structure, and building enclosure. One of these variations is chosen as "typical" for this typical model, and a breakdown is provided that shows the cost and percentages of each building system or component. A description of how to estimate costs from the Means publication is found in the *Technical Manual*. Since Means is published annually, fluctuations in typical building cost can be tracked and the user can insert the most up-to-date Means typical building cost into the default database. This procedure is outlined in the *Technical Manual*.

In **HAZUS**, selected Means models have been chosen from the 70 plus models that represent the 33 occupancy types. The wide range of costs shown, even for a single model, emphasize the importance of understanding that the dollar values shown should <u>only be used to represent costs of large aggregations</u> of building types. If costs for single buildings or small groups (such as a college campus) are desired for more detailed loss analysis, then local <u>building specific</u> cost estimates should be used.

9.5.3.2.2 Building Contents:

Building contents are defined as furniture, equipment that is not integral with the structure, computers, and supplies. Contents do not include inventory or non-structural components such as lighting, ceilings, mechanical and electrical equipment and other fixtures. Unlike HAZUS-99, which default values for contents (by occupancy) as a percentage of the replacement value of the facility, in **HAZUS**, explicit contents exposure are supplied. The damage to contents is expressed in terms of the percentage of damage to the contents based upon the acceleration-sensitive non-structural damage state of the building. The contents damage percentages are based upon the assumption that for the complete damage state some percentage of contents, 15%, can be retrieved. The default contents damage percentages are the same for all occupancies.

9.5.3.2.3 Business Inventory:

Business inventories vary considerably with occupancy. For example, the value of inventory for a high tech manufacturing facility would be very different from that of a retail store. Thus, the default values of business inventory for this model are derived from annual gross sales by assuming that business inventory is some percentage of annual gross sales. These default values are based on judgment.

9.5.3.2.4 Building Cleanup and Repair Time:

A detailed description of repair times is provided in Section 9.6.3.3.

9.5.3.2.5 Relocation Expenses:

Relocation costs may be incurred when the level of building damage is such that the building or portions of the building are unusable while repairs are being made. While relocation costs may include a number of expenses, **HAZUS** only considers disruption costs that may include the cost of shifting and transferring and the rental of temporary space. Relocation expenses are assumed to be incurred only by building owners and measured in $ per square foot per month. A renter who has been displaced from a property due to earthquake damage will cease to pay rent to the owner of the damaged property and will only pay rent to the new landlord. Therefore, the renter has no new rental expenses. It is assumed that the owner of the damaged property will pay the disruption costs for his renter. If the damaged property is owner occupied, then the owner will have to pay for his own disruption costs in addition to the cost of rent while he is repairing his building. Relocation expenses are then a function of the floor area, rental costs per day per square foot, disruption costs, and the expected days of loss of function for each damage state.

9.5.3.2.6 Capital-related Income:

Capital-related income is a measure of the profitability of a commercial enterprise. Income losses occur when building damage disrupts commercial activity. Income losses are the product of floor area, income realized per square foot and the expected days of loss of function for each damage state. The U.S. Department of Commerce’s Bureau of Economic Analysis reports regional estimates of capital-related income by economic sector. Capital-related income per square foot of floor space can then be derived by dividing income by the floor space occupied by a specific sector. Income will vary considerably depending on regional economic conditions. Therefore, default values need to be adjusted for local conditions. Default values were derived from information in Table 4.7 of ATC-13.

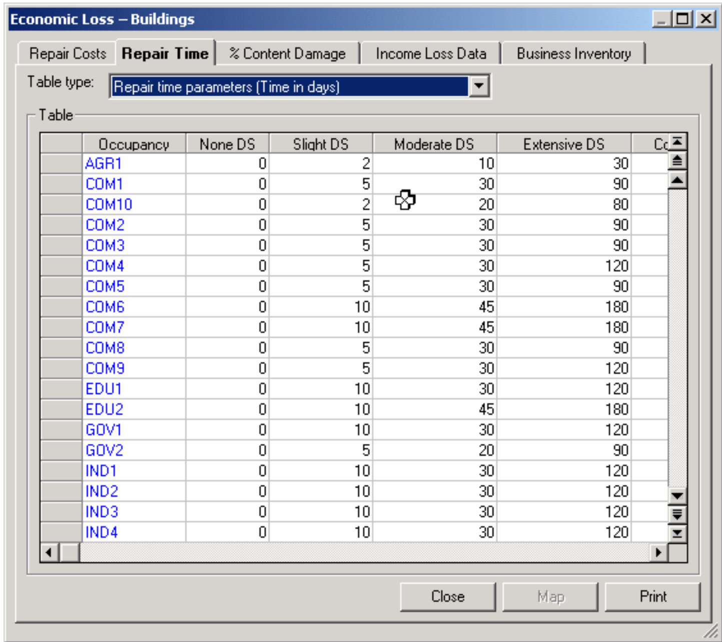
9.5.3.3 Repair and Clean-up Times

The time to repair a damaged building can be divided into two parts: construction and clean-up time, and time to obtain financing, permits and complete a design. For the lower damage states, the construction time will be close to the real repair time. At the higher damage levels, a number of additional tasks must be undertaken that typically will considerably increase the actual repair time. These tasks, which may vary considerably in scope and time between individual projects, include:

- Decision-making (related to businesses of institutional constraints, plans, financial status, etc.)
- Negotiation with FEMA (for public and non-profit), Small Business Administration, etc.
- Negotiation with insurance company, if insured
- Obtaining financing
- Contract negotiation with design firms(s)
- Detailed inspections and recommendations
- Preparation of contract documents
- Obtaining building and other permits
- Bidding/negotiating construction contract
- Start-up and occupancy activities after construction completion

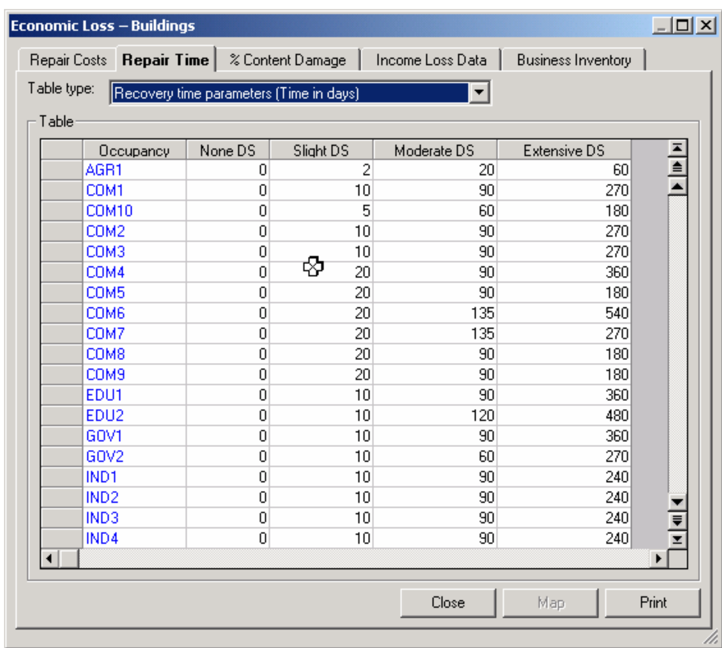
Default building repair and clean-up times are provided with **HAZUS**. These default values are broken into two parts: construction time and extended time. The construction time is the time to do the actual construction or repair. The extended time includes construction plus all of the additional delays described above. A discussion of these values is found in the *Technical Manual*. Default values can be viewed and modified using the window shown in Figure 9.43. Repair times are presented as a function of both amount of damage and occupancy class. Clearly there can be a great deal of variability in repair times, but these represent estimates of the median times for actual cleanup and repair. This window is accessed from the **Analysis|Parameters|Buildings-Economic** menu. To modify these values, type in the desired new values and click on the **Close** button. You will be asked to confirm your changes.

Default values of the extended building cleanup and Figure 9.44 repair times that account for delays in decision-making, financing, inspection etc., are viewed by clicking on the desired table shown in Figure Figure 9.44. Default extended estimates also can be modified.



Occupancy	None DS	Slight DS	Moderate DS	Extensive DS
AGR1	0	2	10	30
COM1	0	5	30	90
COM10	0	2	20	80
COM2	0	5	30	90
COM3	0	5	30	90
COM4	0	5	30	120
COM5	0	5	30	90
COM6	0	10	45	180
COM7	0	10	45	180
COM8	0	5	30	90
COM9	0	5	30	120
EDU1	0	10	30	120
EDU2	0	10	45	180
GOV1	0	10	30	120
GOV2	0	5	20	90
IND1	0	10	30	120
IND2	0	10	30	120
IND3	0	10	30	120
IND4	0	10	30	120

Figure 9.43 Default building repair times.

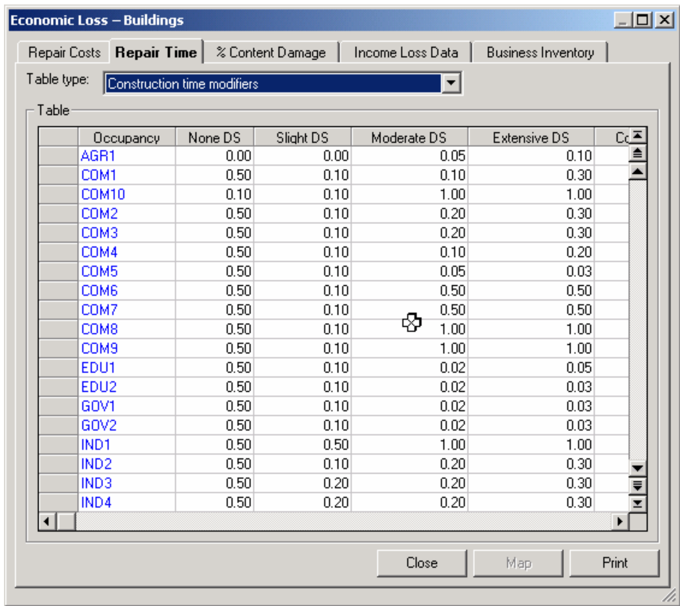


Occupancy	None DS	Slight DS	Moderate DS	Extensive DS
AGR1	0	2	20	60
COM1	0	10	90	270
COM10	0	5	60	180
COM2	0	10	90	270
COM3	0	10	90	270
COM4	0	20	90	360
COM5	0	20	90	180
COM6	0	20	135	540
COM7	0	20	135	270
COM8	0	20	90	180
COM9	0	20	90	180
EDU1	0	10	90	360
EDU2	0	10	120	480
GOV1	0	10	90	360
GOV2	0	10	60	270
IND1	0	10	90	240
IND2	0	10	90	240
IND3	0	10	90	240
IND4	0	10	90	240

Figure 9.44 Default extended building cleanup and repair times.

Repair times differ for similar damage states depending on building occupancy. Simpler and smaller buildings will take less time to repair than more complex, heavily serviced, or larger buildings. It has been also noted that large well-financed corporations can sometimes accelerate the repair time compared to normal construction procedures.

However, establishment of a more realistic repair time does not translate directly into business or service interruption. For some businesses, building repair time is largely irrelevant, because these businesses can rent alternative space or use spare industrial/commercial capacity elsewhere. Thus Building and Service Interruption Time Multipliers have been developed to arrive at estimates of business interruption for economic purposes. These values are multiplied by the extended building cleanup and repair times. Service and building interruption multipliers can be viewed using the window shown in Figure 9.45.



Occupancy	None DS	Slight DS	Moderate DS	Extensive DS	Cc
AGR1	0.00	0.00	0.05	0.10	
COM1	0.50	0.10	0.10	0.30	
COM10	0.10	0.10	1.00	1.00	
COM2	0.50	0.10	0.20	0.30	
COM3	0.50	0.10	0.20	0.30	
COM4	0.50	0.10	0.10	0.20	
COM5	0.50	0.10	0.05	0.03	
COM6	0.50	0.10	0.50	0.50	
COM7	0.50	0.10	0.50	0.50	
COM8	0.50	0.10	1.00	1.00	
COM9	0.50	0.10	1.00	1.00	
EDU1	0.50	0.10	0.02	0.05	
EDU2	0.50	0.10	0.02	0.03	
GOV1	0.50	0.10	0.02	0.03	
GOV2	0.50	0.10	0.02	0.03	
IND1	0.50	0.50	1.00	1.00	
IND2	0.50	0.10	0.20	0.30	
IND3	0.50	0.20	0.20	0.30	
IND4	0.50	0.20	0.20	0.30	

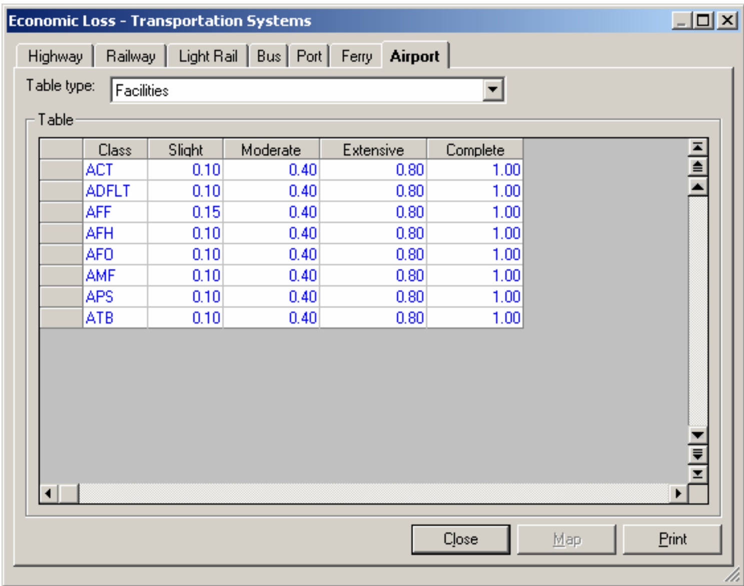
Figure 9.45 Default building and service interruption time multipliers.

Application of the interruption multipliers to the extended building clean up and repair times results in average values for the business or service interruption. For low levels of damage the time loss is assumed to be short, with cleanup by staff, and work can resume while slight repairs are being done. For most commercial and industrial businesses that suffer moderate or extensive damage, the default business interruption time is short on the assumption that businesses will find alternate ways of continuing their activities. Churches will generally find temporary accommodation quickly, and government offices will also resume operating almost at once. It is assumed that hospitals and medical offices can continue operating, perhaps with some temporary rearrangement and departmental relocation, after sustaining moderate damage. However, with extensive damage their loss of function time is assumed to be equal to the total time for repair. For other businesses and facilities, the interruption time is assumed to be equal to, or approaching, the total time for repair. This applies to residential, entertainment, theater, parking, and religious facilities whose revenue or continued service is dependent on the existence and continued operation of the facility.

The median value of repair time applies to a large inventory of facilities. At moderate damage some marginal businesses may close, while others will open after a day's cleanup. Even with extensive damage some businesses will accelerate repair, while a number of others will close or be demolished. For example, one might reasonably assume that a URM building that suffers moderate damage is more likely to be demolished than a newer building that suffers moderate or even extensive damage. If the URM building is a historic structure, its likelihood of survival and repair will probably increase. There will also be a small number of extreme cases: the slightly damaged building that becomes derelict, or the extensively damaged building that continues to function for years with temporary shoring, until an expensive repair is financed and executed.

9.5.3.4 Development of Input for Lifeline Losses

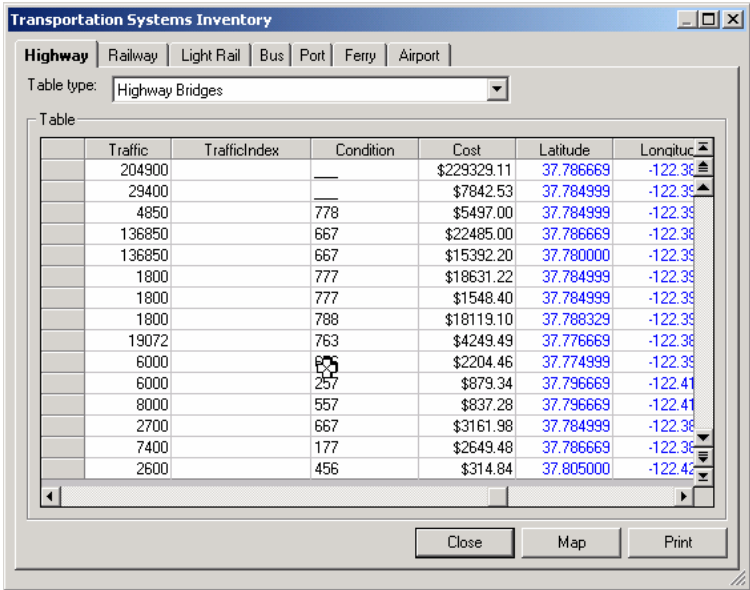
For lifelines, estimates of economic losses are limited to the costs of repair. For each damage state, a default damage ratio has been defined. A damage ratio is the cost of repair as a fraction of the replacement cost. A sample of default damage ratios is shown in Figure 9.46. For example, the cost to repair slight damage to an airport control tower of type ACT is 10% of the replacement cost. This window is accessed from the **Analysis|Parameters|Lifelines-Economic** menu. The damage ratios are defined based upon the model lifeline components discussed in Chapters 7 and 8 of the *Technical Manual*. Development of damage ratios for lifeline components from damage to sub-components is discussed in Section 15.3 of the *Technical Manual*. Damage ratios can be modified to perform sensitivity analyses; however, damage ratios should be kept in the ranges defined in Chapter 15 of the *Technical Manual*.



Class	Slight	Moderate	Extensive	Complete
ACT	0.10	0.40	0.80	1.00
ADFLT	0.10	0.40	0.80	1.00
AFF	0.15	0.40	0.80	1.00
AFH	0.10	0.40	0.80	1.00
AFO	0.10	0.40	0.80	1.00
AMF	0.10	0.40	0.80	1.00
APS	0.10	0.40	0.80	1.00
ATB	0.10	0.40	0.80	1.00

Figure 9.46 Default damage ratios for airport components.

To make estimates of losses to lifelines, damage ratios must be multiplied by replacement costs. Default replacement costs provided with the methodology are mostly based on values found in ATC 13 and ATC-25. Replacement costs can be viewed and modified in the corresponding inventory table ('Cost' field). Figure 9.47 shows an example for highway bridges. All cost fields are in thousands of dollars.



Traffic	TrafficIndex	Condition	Cost	Latitude	Longituc
204900		___	$229329.11	37.786669	-122.38
29400		___	$7842.53	37.784999	-122.39
4850		778	$5497.00	37.784999	-122.39
136850		667	$22485.00	37.786669	-122.38
136850		667	$15392.20	37.780000	-122.39
1800		777	$18631.22	37.784999	-122.39
1800		777	$1548.40	37.784999	-122.39
1800		788	$18119.10	37.788329	-122.39
19072		763	$4249.49	37.776669	-122.38
6000		[illegible]	$2204.46	37.774999	-122.39
6000		257	$879.34	37.796669	-122.41
8000		557	$837.28	37.796669	-122.41
2700		667	$3161.98	37.784999	-122.38
7400		177	$2649.48	37.786669	-122.38
2600		456	$314.84	37.805000	-122.42

Figure 9.47 Replacement costs for highway bridges inventory.

9.6 Running the Indirect Economic Loss Module

Indirect economic impacts are defined in **HAZUS** as the long-term economic impacts on the region that occur as a result of direct economic losses. Examples of indirect economic impacts include changes in unemployment or changes in sales tax revenues.

Earthquakes may produce impacts on economic sectors not sustaining direct damage. Activities that rely on regional markets for their output or that rely on a regional source of supply could experience interruptions in their operations. Such interruptions are called **indirect** economic losses. The extent of these losses depends upon such factors as the availability of alternative sources of supply and markets for products, the length of the production disturbance, and deferability of production.

In a sample economy Company A ships to Company B, and Company B to Company C. C supplies households with a final product and is also a supplier of inputs to A and B. There are two factories producing product B, one of which is destroyed in the earthquake. Indirect damages occur because: 1) direct damage to production facilities and inventories cause supply shortages for firms needing these; 2) because damaged production facilities reduce their demand for inputs from other producers; or 3) because of reductions in government, investment, or export demands for goods and services caused by an earthquake.

The supply shortages caused as a result of losing B could cripple C, providing C is unable to locate alternative sources. Three options are possible: 1) secure additional supplies from outside the region (imports); 2) obtain additional supplies from the undamaged factory (excess capacity); and 3) draw from B's inventories.

Modeling of a regional economy is a very complex problem if it is to include such factors as the ability to replace lost inventory or lost production by products from other regions. The model included with **HAZUS** is a simplified model based on a set of equations that were derived from a statistical analysis of a large number of loss scenarios. Therefore, while it will give the user insight into the possible consequences of an earthquake, a more detailed model may be necessary to accurately represent the individual characteristics of a particular region.

To run this module, select the **Indirect economic impact** option in the **Analysis|Run...** menu (see Figure 9.48).

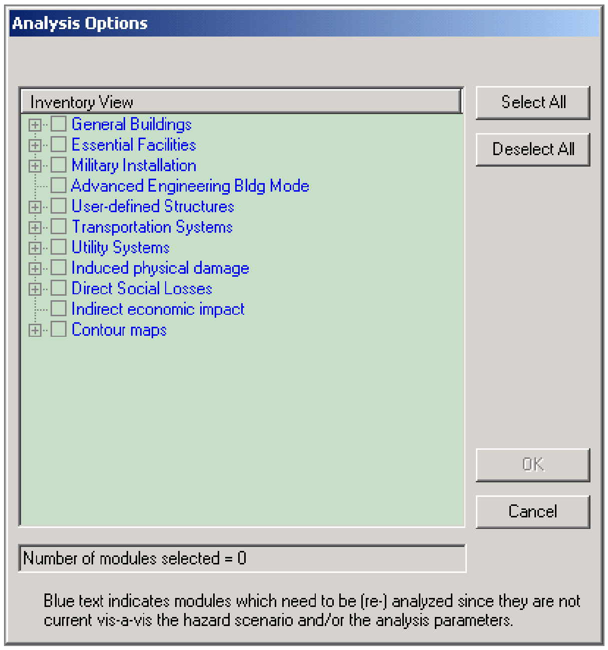


Figure 9.48 HAZUS analysis options.

9.6.1 Economic Sectors

To simplify modeling, the regional economy has been divided into 10 sectors as follows:

- Agriculture
- Mining
- Construction
- Manufacturing
- Transportation
- Trade (Wholesale and Retail)
- Finance, Insurance and Real Estate
- Services
- Government
- Other

Changes in payroll, employment, etc., are reported for each of these economic sectors.

9.6.2 Running the Indirect Economic Loss Module with a Synthetic Economy

Estimates of indirect losses can be calculated using a very simplified model of the regional economy. **HAZUS** contains twelve built-in "synthetic" economies. These "synthetic economies" are based on aggregating characteristics from a number of regional economies around the country and creating three typical economy types:

- Primarily manufacturing
- Primarily service with manufacturing as the secondary sector
- Primarily service with trade as the secondary sector

Each economy is broken into four size classifications:

- Super (greater than 2 million in employment)
- Large (greater than 0.6 million but less than 2 million in employment)
- Mid Range (greater than 30,000 but less than 0.6 million in employment)
- Low (less than 30,000 in employment)

The indirect economic impact module selects the most appropriate synthetic economy to use for the study region based on user inputs describing the size of the economy (number of employees) and the type of economy. In order to run the module using a synthetic economy, you must identify the type and size of economy using the window shown in Figure 9.49. To access the screen, select the **Indirect economic** option in the **Analysis|Parameters** menu.

The default type of economy is "primarily manufacturing." You should overwrite this if "service/manufacturing" or "service/trade" is a more accurate characterization of your region. The economy type can be determined by evaluating the percent of regional employment in each of the major industries. For further guidance, consult the *Technical Manual*.

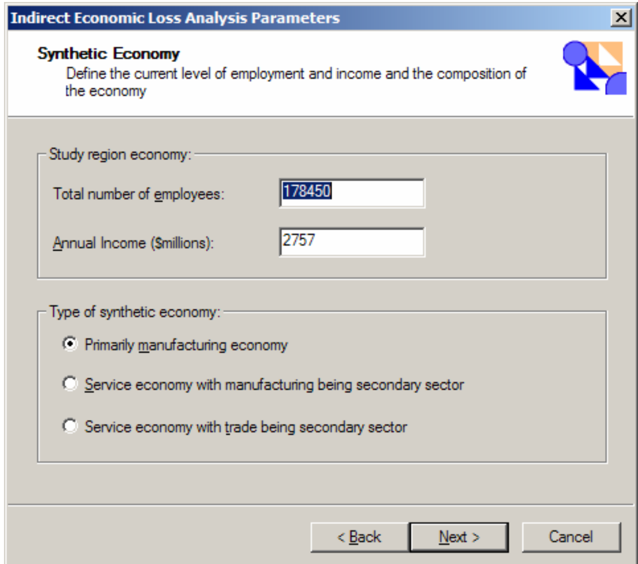


Figure 9.49 Setting parameters for synthetic economy.

HAZUS provides a default employment figure based on the counties in the study region. The source of this default data is the Bureau of Economic Analysis. You should review this number against available local information and overwrite it if appropriate. Employment should be measured by place of *work* rather than by place of *residence*. This distinction is especially significant when there is substantial commuting across the region's borders. In addition to employment, the default figure provided for regional income should be reviewed and overwritten if appropriate.

After you have defined the synthetic economy and clicked on the **Next>** button in Figure 9.49 the window in Figure 9.50 will appear. Figures 9.52 through 9.55 allow you to modify economic factors that relate to the general capacity and the economy's ability to restore itself following the earthquake. Default values for all of the factors are provided for use in analysis. However, you should still review at the least the following factors and replace the default values as appropriate:

- Unemployment rate
- Level of outside aid and/or insurance
- Interest rate on loans

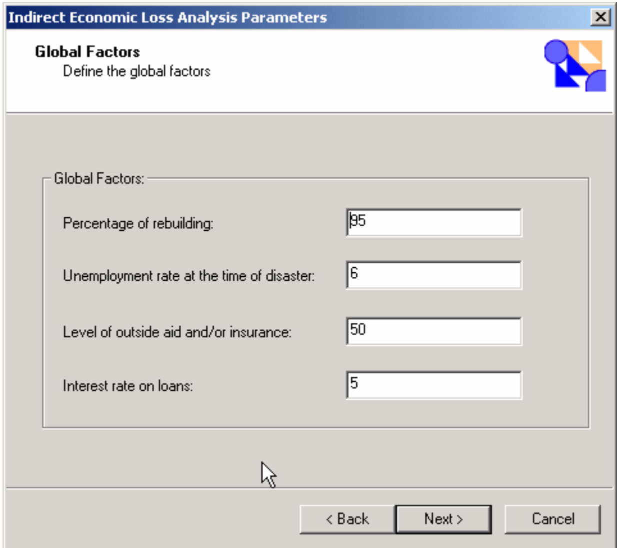


Figure 9.50 Setting the indirect economic factors.

Default values are provided for four global factors as shown in Figure 9.50. The **Percentage of rebuilding** is used by the module to estimate the size of the reconstruction stimulus to the economy. The **Unemployment rate at the time of the disaster** serves as an indicator of excess capacity or slack in the economy; the indirect losses are generally higher when the economy has low unemployment because there is less unused capacity that can help make up for capacity lost due to earthquake damage. The **Level of outside aid and/or insurance** is a major determinant of the long-term income effects of the disaster since the amount of reconstruction funded by borrowing within the region will in the long term cause indebtedness. The **Interest rate on loans** also affects the amount of indebtedness arising from reconstruction financing.

Again, these should be reviewed and modified where appropriate. In some cases you may wish to run several analyses using different values, such as **Level of outside aid and/or insurance**, to investigate the effect of this parameter on indirect economic impacts. When you have finished with the **Factors** tab, click on the **Restoration & Rebuilding** tab to view the screen in Figure 9.51.

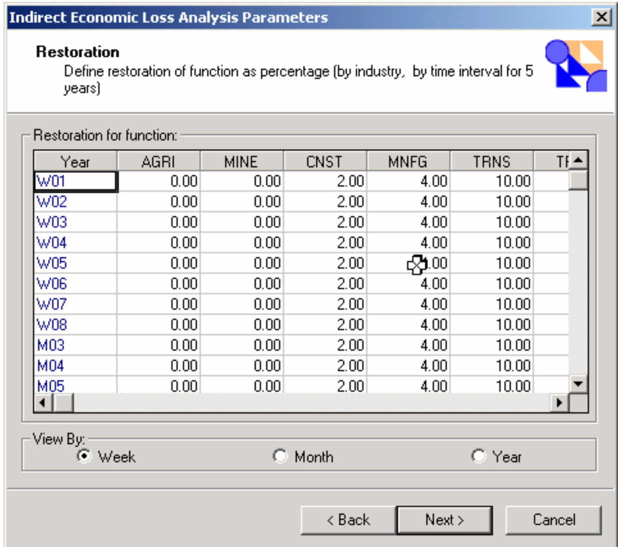


Figure 9.51 Setting the indirect economic restoration and rebuilding factors.

The dialog shows default values for industry restoration functions for each of the first 5 years. Units are in percentage points of industry *loss* of function or production capacity in each year. Default values may be overwritten for consistency with results related to physical damage (See section 16.5.2.2 in the *Technical Manual*).

The rebuilding factors as shown in Figure 9.52 has default values for "% of Total Rebuilding Expenditures" in each of the first 5 years for buildings and lifelines, respectively. In general, most of the rebuilding is expected to occur in the first 1-2 years after the disaster. Lifeline reconstruction expenditures are expected to be made proportionately earlier than buildings reconstruction. Default values can be overwritten for consistency with results on physical damage (See the *Technical Manual* for more information).

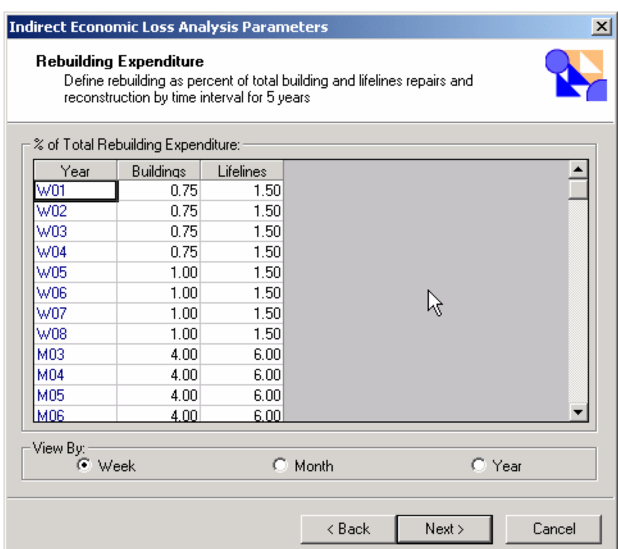


Figure 9.52 Setting the indirect economic rebuilding factors

The last factors that can be altered are the Stimulus Values. By clicking on the Stimulus Values tab, you can access the screen shown in Figure 9.53.

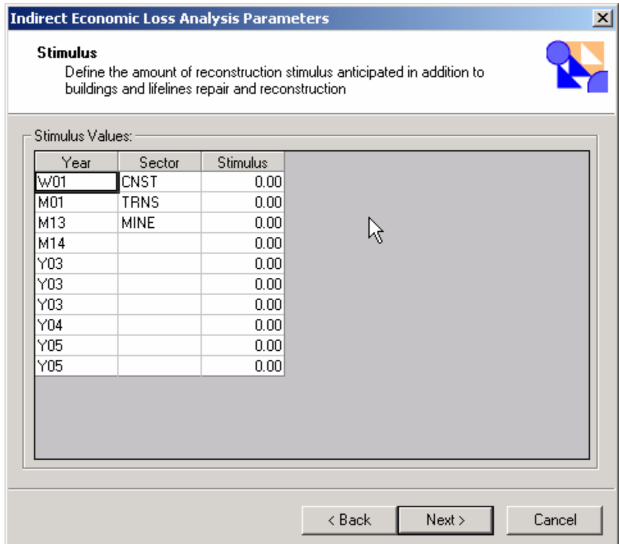


Figure 9.53 Setting the stimulus values

The parameters in Figure 9.58 represent an anticipated stimulus to the economy in addition to repair and reconstruction of buildings and lifelines. The defaults are all zero.

HAZUS includes the capability of inputting a higher resolution timeframe for the restorations factors, the rebuilding factors and the stimulus values. In **HAZUS** the factors can be specified on a weekly basis for the first 2 months (8 weeks), on a monthly basis for the first 2 years (month 3 through 24), and yearly thereafter (year 3 through 5.)

Click **OK** after completing selections on this screen. This completes the user input requirements. The module can be run by clicking on the **Indirect economic loss** option in the **Analysis|Run...** menu.

9.6.3 Running the Indirect Economic Loss Module with IMPLAN Data

For a more realistic analysis the indirect economic module can use IMPLAN data for modeling the economy. Select **Use IMPLAN data files** from the **Indirect Economic Analysis Type** screen in Figure 9.54. The default employment and income figures on the screen will not be used. Instead, the module will automatically pick off more accurate data from the IMPLAN data files you provide (see the *Technical Manual*). You do not have to make a selection under **Type of Synthetic Economy**.

Click **OK** after completing selections on this screen and the **IMPLAN** Files screen shown in Figure 9.59 will appear.

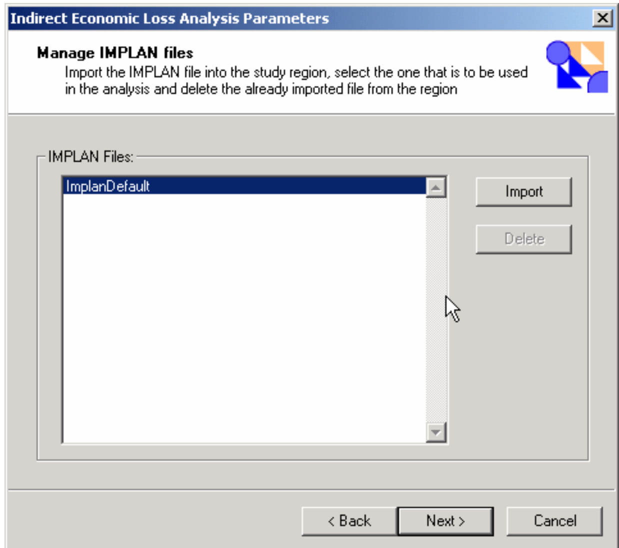


Figure 9.54 Screen for importing IMPLAN files.

The screen contains a box listing available **IMPLAN** files. If the user has not imported any files, only one file labeled **IMPLANDF** (for IMPLAN default) is listed. This indicates the default synthetic economy.

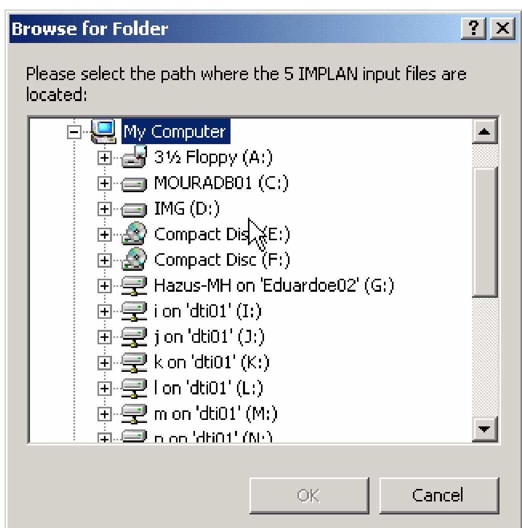


Figure 9.55 Locating IMPLAN files.

Use the **Import** button to import **IMPLAN** files into **HAZUS**. Note that **HAZUS** only prompts you for the directory that contains the required files. All five files should be located in the same directory. Chapter 16 of the **HAZUS** Technical Manual provides the information of the files required by the module.

The newly imported **IMPLAN** file name now appears underneath **IMPLANDF**. Use the mouse to highlight the new **IMPLAN** file, thus selecting it for use in the analysis. Click **OK** and the Indirect Economic Analysis Factors screen will appear.

If you have previously imported an **IMPLAN** data file(s), its name(s) will appear on the list. Remember to highlight the correct file each time before clicking **OK** to ensure that **HAZUS** does not return to using the default **IMPLANDF** file.

Follow the steps outlined in Section 9.6.2 for specifying indirect economic analysis factors. Run the module by clicking on the **Indirect economic loss** option in the **Analysis|Run...** menu.

9.7 Dealing with Uncertainty

As was mentioned earlier, **HAZUS** does not explicitly include uncertainty. The results obtained will be mean (or average) values of losses, and do not include ranges that would help you estimate bounds on your results. To some extent you can examine the variability of the model by performing a sensitivity analysis.

In a sensitivity analysis you would change inputs or parameters one at a time and see how sensitive the results are to these changes. For example, you might modify the scenario earthquake by one half magnitude up or down and rerun your analysis. Obviously if you increase the magnitude, for example from 6.0 to 6.5, the losses will increase. The question is how much. If the results change a great deal then your model is very sensitive to this input and you should evaluate that input carefully to make sure you are using a reasonable value. This may involve obtaining the advice of an expert. Alternatively, when you write the final report you can provide a range of losses based on the high and low values you obtain from your sensitivity analysis. On the other hand, if the results don't vary significantly, then you don't have to worry a great deal about the exact value of the parameter or input.

Types of inputs that you may wish to alter in your sensitivity analysis are listed below. This list contains suggestions only and is not intended to be comprehensive.

- Magnitude of scenario earthquake (up or down 1/2 magnitude)
- The attenuation relationship used (choose from the relationships supplied with **HAZUS**)
- Mix of construction quality levels (inferior, code and superior)
- Repair and replacement costs
- Fire module wind speed and engine speed
- Shelter module utility, modification and weighting factors
- Type of economy in indirect module
- Amount of outside aid in indirect module
- Unemployment rate in indirect module
- Interest rate on loans in indirect module

The user can modify inputs depending on the time and resources available. It is important to remember, though, that you must alter them one at a time if you want to be able to see any trends due to a particular parameter. It is suggested that you set up a system for keeping track of the results so that you understand which inputs produced which results. You might set up a tables such as Table 9.10and Table 9.11 to record inputs and results.

Table 9.10 Sample Table of Sensitivity Analysis Scenarios

Scenario Name	Inputs Magnitude	Const. Quality Mix
Port1	6.0	default
Port2	6.0	new
Port3	6.5	default
Port4	6.5	new
Port5	5.5	default
Port6	5.5	new

Table 9.11 Sample Table of Sensitivity Analysis Results

Value	Port1	Port 2	Port3	Port4	Port5	Port6
Direct Economic Losses						
Cost Structural Damage	$300,000	$310,000	$350,000	$365,000	$260,000	$270,000
Cost Non-Structural Damage	•	•	•	•	•	•
Cost Contents Damage	•	•	•	•	•	•
Inventory Loss	•	•	•	•	•	•
Relocation Loss	•	•	•	•	•	•
Capital Related Income Loss	•	•	•	•	•	•
Wage Losses	•	•	•	•	•	•
Rental Income Loss	•	•	•	•	•	•
Total Loss						
Transportation System Dollar Loss						
Highway						
Railway						
Light Rail						
Bus						
Port						
Ferry						
Airport						
Total Loss						
Utilities System Dollar Loss						
Potable Water						
Waste Water						
Oil						
Natural Gas						
Electric Power						
Communication						
Total Loss						
Casualties						
Severity 1						
Severity 2						
Severity 3						
Severity 4						
Shelter Needs						
•						
•						

Chapter 10. Viewing and Reporting the Results

10.1 Guidance for Reporting Loss Results

There is no single format that is appropriate for presentation of loss study results. The format will depend on the use of the results and the intended audience. The audience can vary from the general public to technical experts. Decision makers such as city council members and other government officials may require only summaries of losses for a region. Emergency response planners may want to see the geographical distribution of all losses and damage for several different earthquake scenarios. **HAZUS** provides a great deal of flexibility in presenting results. Results can be presented in a tabular or map form - which maps or tables are selected for reports will depend on the application. In any case, the users of the results should be involved from the beginning in determining the types and formats of the results that best suit their needs.

In previous loss studies, authors of reports have had the difficult task of trying to combine the study results with the theory of how they were calculated. Consequently, reports often seemed overly technical, reducing their readability and usefulness for many audiences. **HAZUS** users can refer to the *Technical Manual* that describes all of the theories and equations that provide the basis of any loss estimate. Thus reports do not need to, <u>and probably should not</u> include technical discussions of theory. Instead, reports should focus on describing results in non-technical language that is easily understood by the intended audience.

While no particular format for presenting results can be recommended, several general statements about reporting of results can be made. Reports should serve to clarify the meaning of the loss estimates. As an example, the reporting of economic loss should indicate whether both direct and indirect losses are included in the estimates. The report should indicate whether losses are due only to structural and non-structural damage or if they also include monetary losses resulting from loss of function. Casualty reports should indicate that casualties include only those that result from building damage and bridge collapse and do not include injuries and deaths from fires, flood, hazardous material releases or medical causes such as heart attacks. It should be clarified that in most cases losses are not calculated for specific buildings or facilities, but instead are based on the performances of entire classes of buildings and lifelines. These are just a few examples of the types of clarifications that should appear in reports.

Reports should also clarify for the reader what assumptions were made in developing the scenario and inventory and in calculating losses. For example, were losses based on default inventories or were default inventories augmented? Were default repair costs and repair times used? If not, what values were used? Were soils maps provided or were results based on a default soil type? What assumptions were made in selecting the scenario earthquake? Is it based on an historical event? Is it based on a specified probability of occurrence (e.g. 10% chance in 200 years)? What types of assumptions were made about design and construction quality?

A criticism of past studies is that there has been little qualitative or quantitative treatment of uncertainty. Discussions with users of previous studies have indicated that users need information about where errors in prediction are most likely to occur. While this methodology does not explicitly include a technique for carrying the uncertainty of each variable through the entire set of calculations, sensitivity analyses are useful for providing bounds on loss estimates (see Section 9.7). At a minimum, reports should make some statement about the uncertainty of the input values.

10.2 Module Outputs

Each of the modules of **HAZUS** provides the user with a series of outputs. The outputs can be in a numerical or graphical form. Ground motion and failure is calculated at different locations for a specified earthquake scenario. This information by itself may not be very useful for hazard mitigation and emergency planning. However, ground shaking results are used as an input to determine the structural and non-structural damage.

10.3 Potential Earth Science Hazards

HAZUS provides information about the expected ground shaking response for a specified event in the given study region. The user may specify a deterministic scenario event. For the purposes of emergency response and preparedness, a scenario event is commonly used to estimate earthquake consequences and losses. The user can also opt for a pseudo-probabilistic approach that can be used to compute expected annual losses. This type of approach may be useful for comparing mitigation strategies. The user can apply an existing ground motion map prepared by an expert.

Table 10.1 summarizes the module outputs for these three options. In all three cases, the user is provided with ground shaking in the study region characterized in terms of peak ground acceleration (PGA) and spectral accelerations (5% damping) at two specific structural periods (0.3 and 1.0 seconds).

Table 10.1 Ground Motion/Site Effects Output

Input	Description of Output	Measure
Deterministic Event	**HAZUS** determines census tract ground motion and develops region-wide ground motion contour maps based on a user-defined scenario event.	a) Census Tract Ground Shaking b) PGA Contour Maps c) Spectral Contour Maps
USGS Probabilistic Seismic Hazard Maps	**HAZUS** includes spectral contour maps at two seismic hazard levels: 2% probability of exceedance in 50 years and 10% probability of exceedance in 50 years	a) PGA Contour Maps b) Spectral Contour Maps
User-Supplied Ground Shaking Maps	The user supplies region-wide ground motion contour maps which are used as the ground motion inputs to **HAZUS**	a) Census Tract Ground Shaking b) PGA Contour Maps c) Spectral Contour Maps

For areas identified as susceptible, **HAZUS** provides information concerning the probability of an expected level of permanent ground deformations (PGD) due to the specified scenario event. In this methodology, permanent ground deformation is defined as liquefaction, landsliding and surface fault rupture. PGD are important in estimating losses to and functionality of lifelines. Table 10.2 summarizes the ground deformation outputs. PGD are reported in terms of contour maps of ground deformations (in meters) or site specific PGD.

Table 10.2 Ground Deformation Output

Input	Description of Output	Measure
Liquefaction	**HAZUS** determines the probability of and expected level of permanent ground deformations for liquefaction susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD
Landsliding	**HAZUS** determines the probability of and expected level of permanent ground deformations for landsliding susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD
Surface Fault Rupture	**HAZUS** determines the probability of and expected level of permanent ground deformations for surface fault rupture susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD

Access the potential hazard outputs from the **Results|Ground Motion** menu (See Figure 10.1). Ground motion maps can be viewed in two forms: census tract-based or contour maps. To generate census tract-based maps, **HAZUS** evaluates the ground motion at the census tract centroid and then assigns the value to the census tract. The census tract-based information is used to derive the damage and loss estimates for the general building stock. Contour maps that are generated by **HAZUS** are for display purposes only. Contour maps that are digitized and entered by the user can be used for further computations.

From the **Ground Motion or Failure** menu, you can plot a variety of maps by choosing one of the options**:** **Ground Motion (By Census Tracts)** or **Contours or Ground Failure Maps**. For the **Ground Motion (By Census Tracts)** option, as shown in Figure 10.2, you can generate acceleration, displacement, velocity, PGV or PGA maps by clicking on the appropriate column of data and then clicking on the **Map** button. Examples of these maps are found in Figures 10.3 and 10.4. For the **Contours or Ground Failure Maps** option, you may plot any of the parameters shown in Figure 10.5 provided that you have already run the specific analysis that you want to plot. Click on your choice in Figure 10.5, followed by the **Map** button.

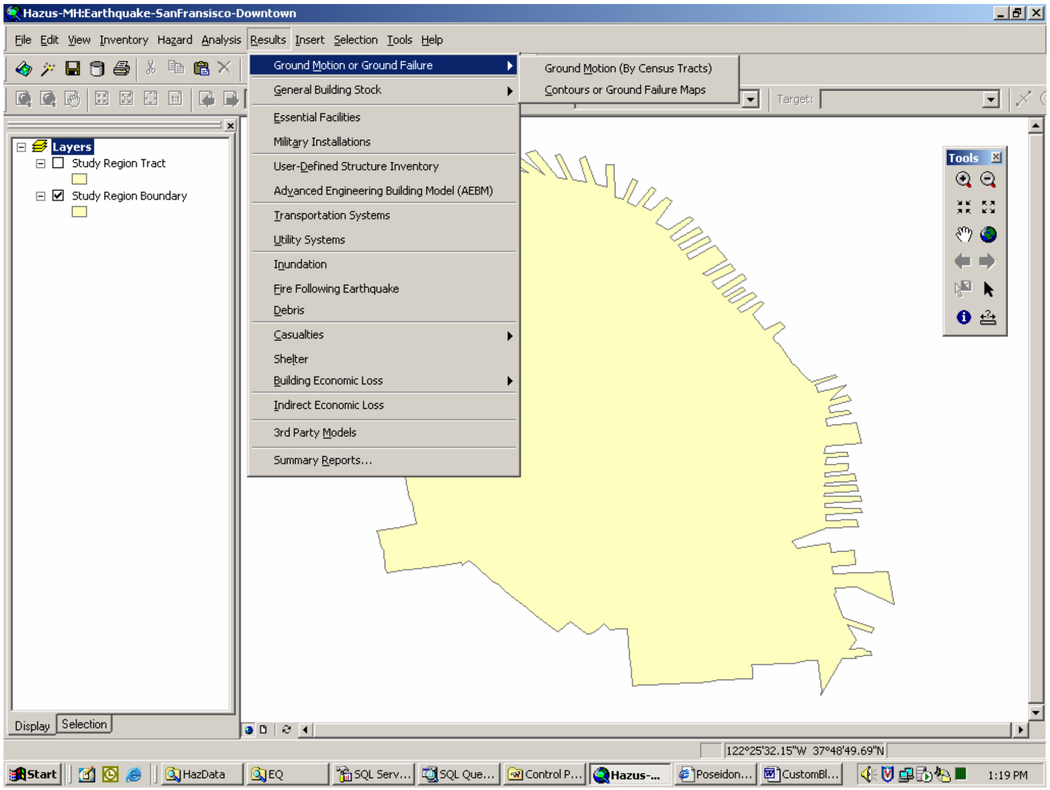
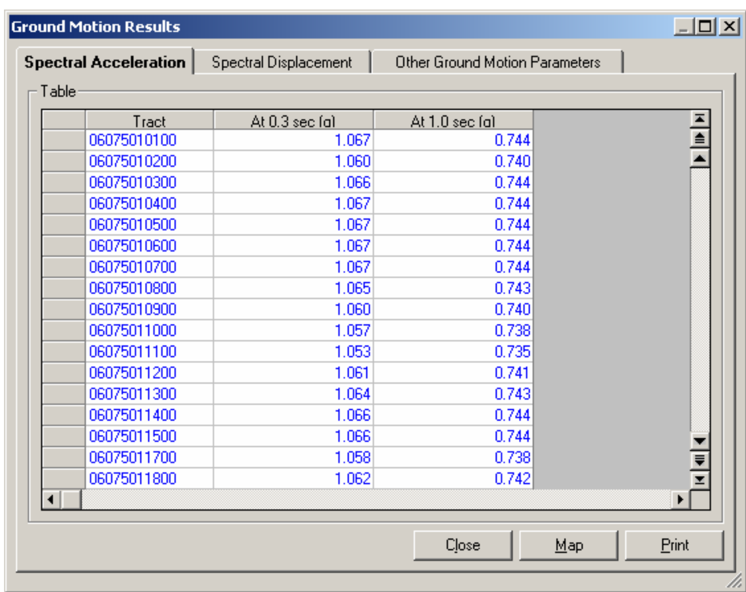


Figure 10.1 Ground motion results.



Tract	At 0.3 sec (g)	At 1.0 sec (g)
06075010100	1.067	0.744
06075010200	1.060	0.740
06075010300	1.066	0.744
06075010400	1.067	0.744
06075010500	1.067	0.744
06075010600	1.067	0.744
06075010700	1.067	0.744
06075010800	1.065	0.743
06075010900	1.060	0.740
06075011000	1.057	0.738
06075011100	1.053	0.735
06075011200	1.061	0.741
06075011300	1.064	0.743
06075011400	1.066	0.744
06075011500	1.066	0.744
06075011700	1.058	0.738
06075011800	1.062	0.742

Figure 10.2 Selecting site-specific data generated in the PESH module

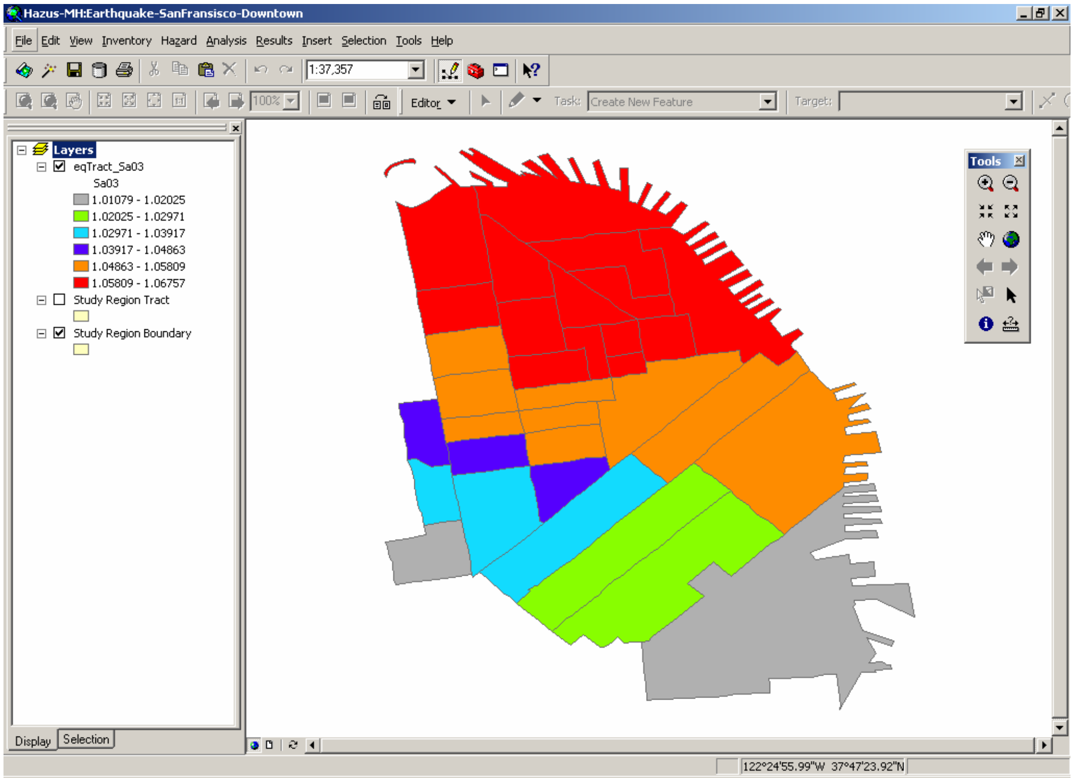


Figure 10.3 Map of 0.3 second spectral acceleration by census tract

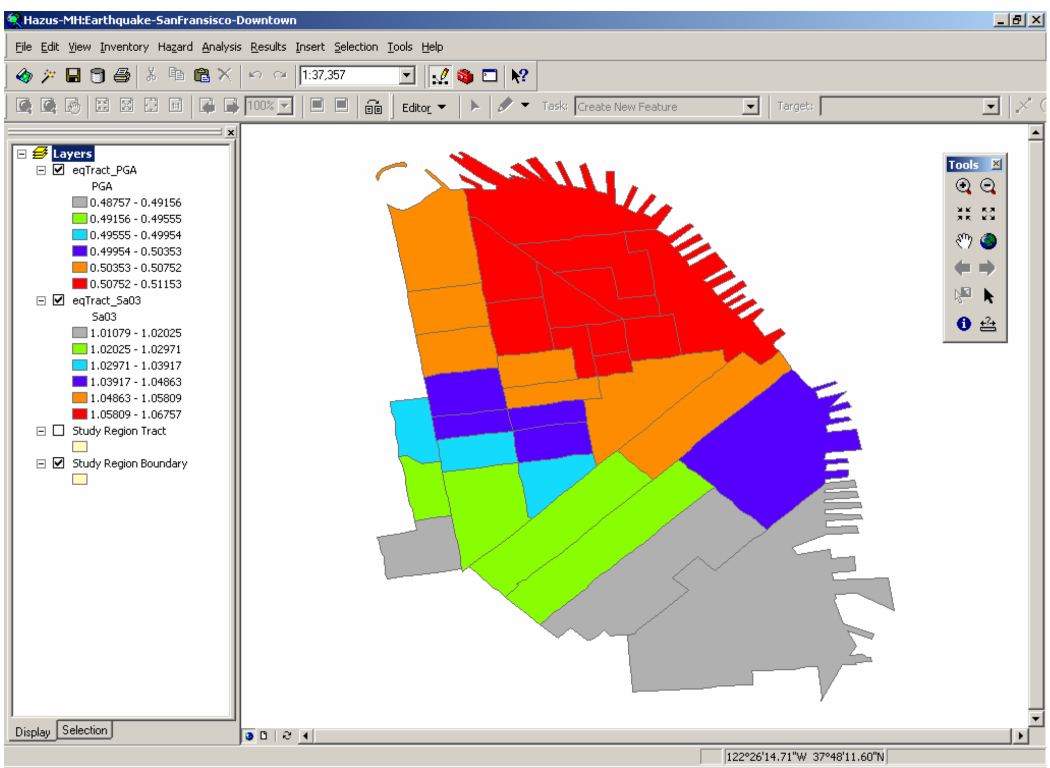


Figure 10.4 Map of peak ground acceleration by census tract.

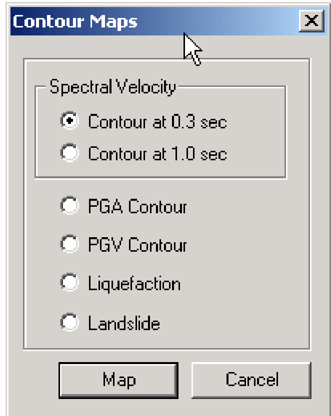


Figure 10.5 Window to select PESH contours for mapping.

10.3.1 Ground Motion Descriptions

Many of the earlier regional loss estimation studies and methods have based losses on MMI and isoseismal maps (maps showing areas of constant MMI). In **HAZUS**, Potential Ground Acceleration (PGA), Potential Ground Velocity (PGV) and Spectral Acceleration (SA) characterize ground shaking. The use of spectral acceleration allows **HAZUS** to account for possible amplification of building motion and consequently damage due to sympathetic response of a building to the earthquake motions.

Sympathetic response of a building (or amplification of building shaking) is similar to what you experience when on a swing. If you pump your legs at a certain frequency, the swing will go very high and very fast. If the ground motion shakes the building at a certain frequency the building will experience amplification of its motions. Fast shaking excites short buildings and slower shaking excites tall buildings. Presenting ground motion in terms of spectral velocity and spectral acceleration gives information about the frequency of the ground shaking. This in turn can be used to determine which buildings (tall or short) are most excited and thus most damaged by a particular earthquake.

10.4 Direct Physical Damage - General Building Stock

The direct physical damage module of **HAZUS** provides information about the level of damage to the study region's general building stock. Damage to the general building stock is not evaluated on a building-by-building basis. Instead, damage is estimated and reported for groups of buildings in each census tract. Damage to the general building stock is defined in terms of the probability that a specific model building type will reach or exceed a specified level of damage when subjected to a given level of ground motion. Damage estimates are then converted in other modules into monetary losses and social losses such as casualties and shelter demands (see, for example, Figure 10.6).

Losses such as the costs of reconstruction, the length of business interruption, the number of people needing shelter and the severity of injuries and number of casualties all depend on the severity of the damage. While estimation of social and economic losses is the ultimate goal of a loss study, some knowledge of the geographical distribution of damage may be helpful in planning for post-earthquake response or in determining strategies for mitigation, for example, if the scenario identifies a particular area where a large number of buildings are likely to collapse, planning for rescue efforts in this area may be important.

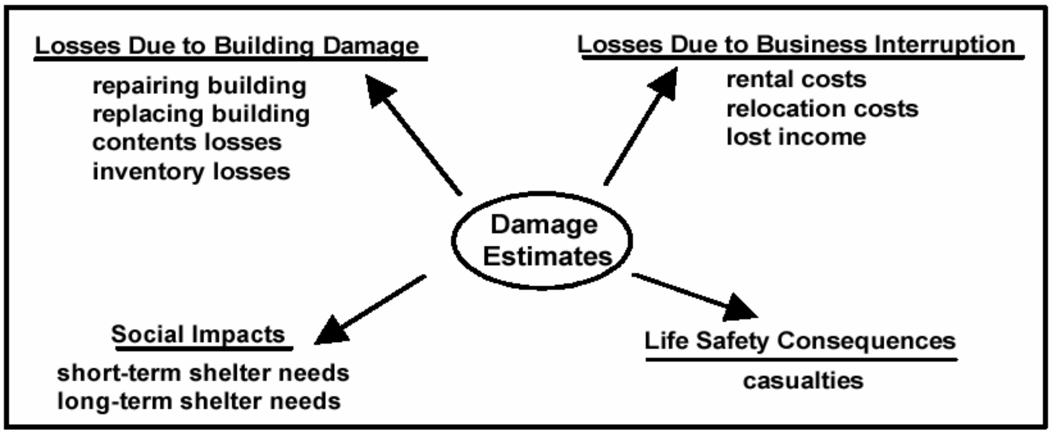


Figure 10.6 Losses calculated from damage estimates.

Damage is described by five damage states (none, slight, moderate, extensive and complete) that are defined in detail in Section 9.3.2. Estimates of earthquake damage are provided in terms of damage state probabilities or building count. For a specified earthquake, the user is provided with the probability of a structural type experiencing a certain level of damage.

For example, for a given earthquake, wood frame structures may have a probability of 0.9 of experiencing no damage and a probability of 0.1 of experiencing slight damage. As shown in Table 10.3, damage state probabilities are provided for structural as well as non-structural damage, where as building counts are only provided for structural damage. To provide the most flexibility to the user, the module delivers damage state probabilities for model building types, specific occupancy classes and general occupancy classes. Results are available in a tabular or map format.

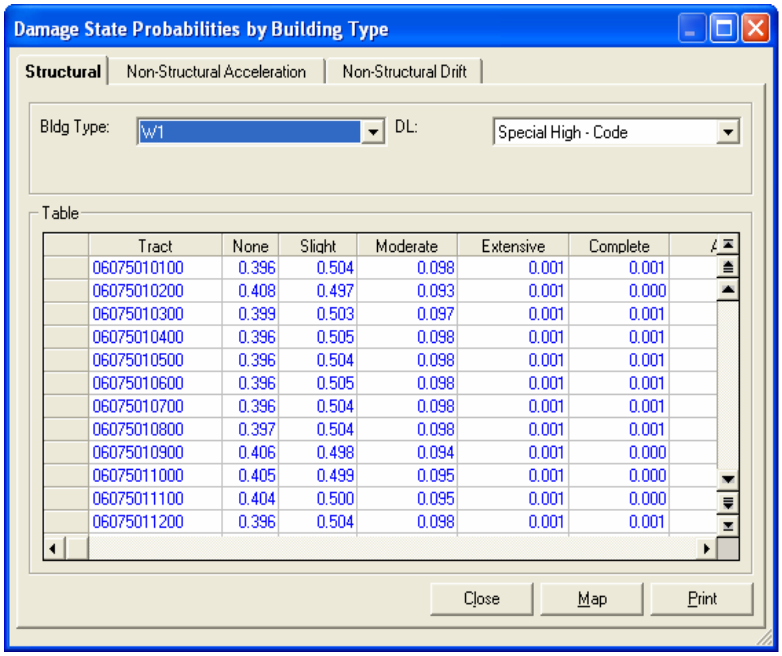
Table 10.3 Direct Physical Damage Outputs - General Building Stock

Input	Description of Output	Measure
Model Building Type	**HAZUS** determines the damage state probability for each model building type (36) by census tract in the study region. Results are presented for each design level. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Building Counts
General Building Type	**HAZUS** determines the damage state probability for each general building type (7) by census tract in the study region. Results are presented for each design level. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Building Counts
Specific Occupancy Class	**HAZUS** determines the damage state probability for each specific occupancy (28) by census tract in the study region. Results are presented for each design level. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Occupancy Counts
General Occupancy Class	**HAZUS** determines the damage state probability for each general occupancy (6) by census tract in the study region. Damage state probabilities are determined for I) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Occupancy Counts

The **Results|General Building Stock** menu option is used to assess the output of the damage module. Results are provided in a tabular format (see Figures 10.7 and 10.8) or in a map form (Figures 10.9 and 10.10). In both cases the following information can be displayed:

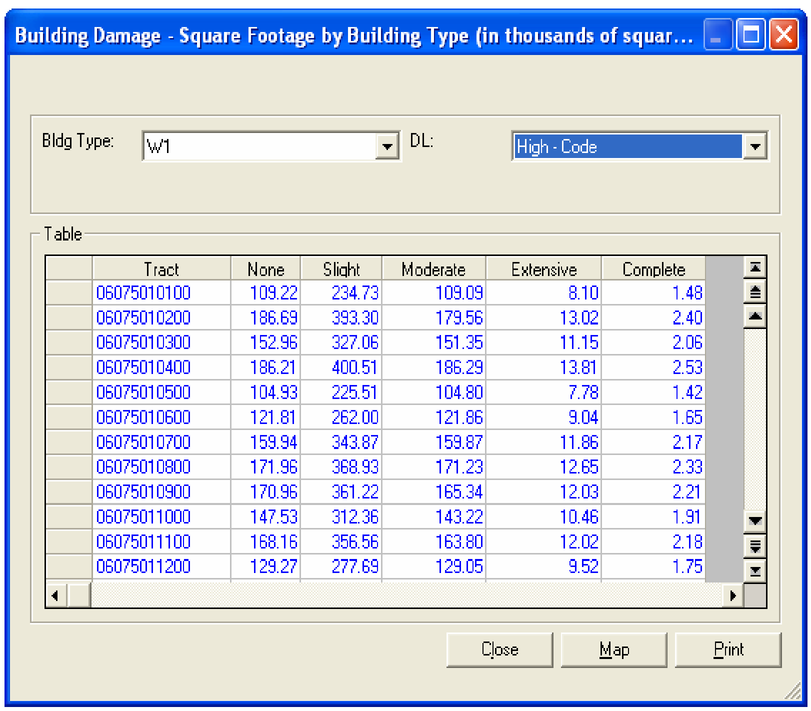
- Probability of none, slight, moderate, extensive or complete structural damage, acceleration sensitive non-structural damage or drift sensitive non-structural damage.
- Probability of at least slight, at least moderate, at least extensive for structural or either type of non-structural damage.

To thematically map a given value, select its column by clicking on the header, and then clicking **Map** and close the dialog.



Tract	None	Slight	Moderate	Extensive	Complete
06075010100	0.396	0.504	0.098	0.001	0.001
06075010200	0.408	0.497	0.093	0.001	0.000
06075010300	0.399	0.503	0.097	0.001	0.001
06075010400	0.396	0.505	0.098	0.001	0.001
06075010500	0.396	0.504	0.098	0.001	0.001
06075010600	0.396	0.505	0.098	0.001	0.001
06075010700	0.396	0.504	0.098	0.001	0.001
06075010800	0.397	0.504	0.098	0.001	0.001
06075010900	0.406	0.498	0.094	0.001	0.000
06075011000	0.405	0.499	0.095	0.001	0.000
06075011100	0.404	0.500	0.095	0.001	0.000
06075011200	0.396	0.504	0.098	0.001	0.001

Figure 10.7 Damage state probabilities by specific building type.



Tract	None	Slight	Moderate	Extensive	Complete
06075010100	109.22	234.73	109.09	8.10	1.48
06075010200	186.69	393.30	179.56	13.02	2.40
06075010300	152.96	327.06	151.35	11.15	2.06
06075010400	186.21	400.51	186.29	13.81	2.53
06075010500	104.93	225.51	104.80	7.78	1.42
06075010600	121.81	262.00	121.86	9.04	1.65
06075010700	159.94	343.87	159.87	11.86	2.17
06075010800	171.96	368.93	171.23	12.65	2.33
06075010900	170.96	361.22	165.34	12.03	2.21
06075011000	147.53	312.36	143.22	10.46	1.91
06075011100	168.16	356.56	163.80	12.02	2.18
06075011200	129.27	277.69	129.05	9.52	1.75

Figure 10.8 Damage state by square footage by building type.

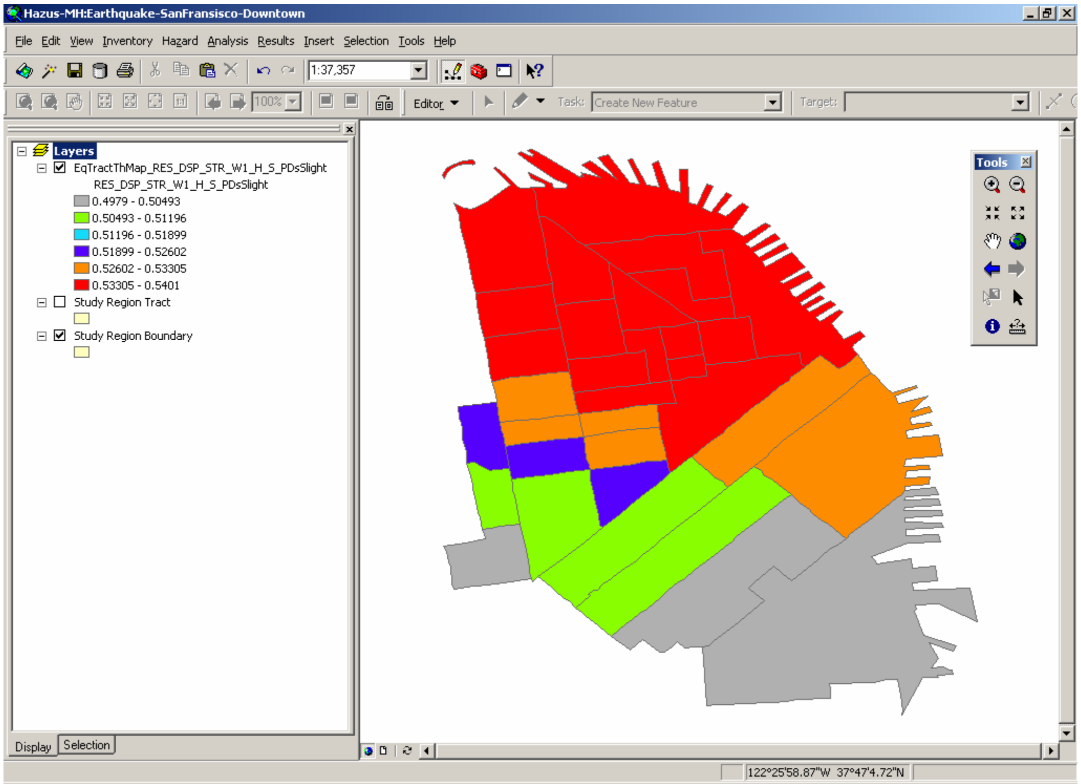


Figure 10.9 Map of probability of slight structural damage.

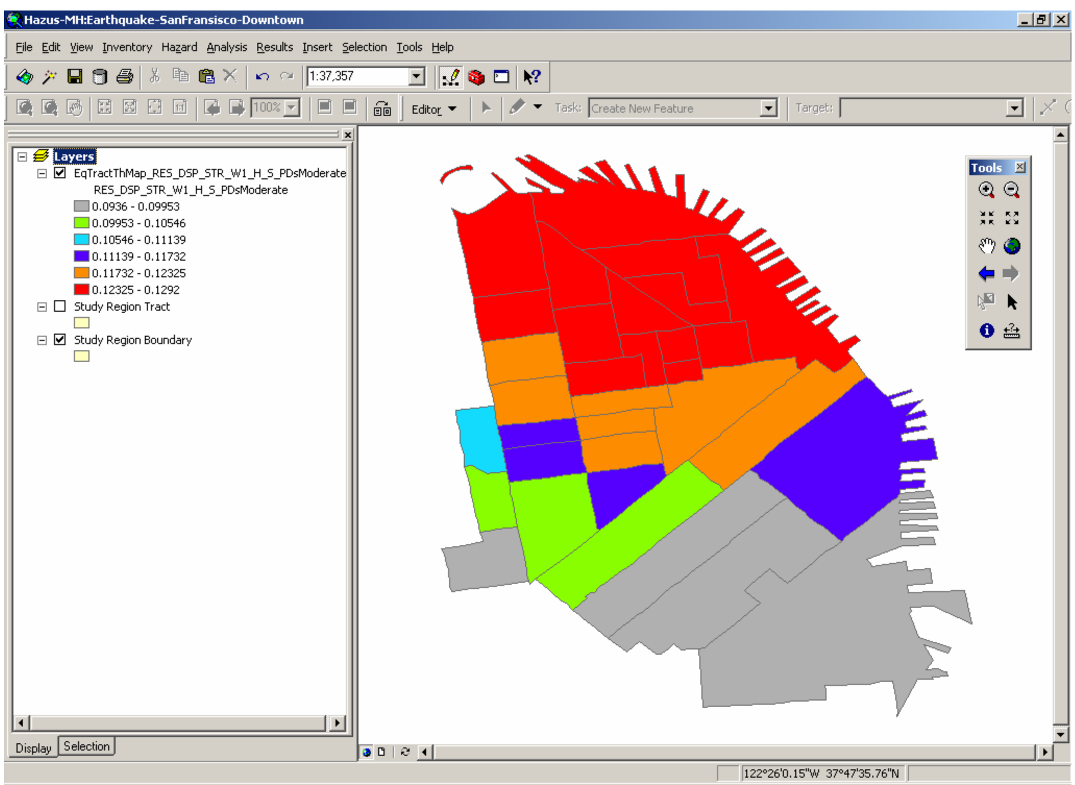


Figure 10.10 Map of moderate structural damage.

10.5 Direct Physical Damage - Essential Facilities

HAZUS provides information about the damage state probability of the study region's essential facilities. In contrast to the general building stock, where damage probabilities are calculated for groups of buildings, for essential facilities the damage probabilities are estimated for each individual facility. As with the general building stock, the damage states are none, slight, moderate, extensive and complete. Both structural and non-structural damage is considered. As can be seen in Table 10.4, damage state probabilities are estimated for health care facilities, police and fire stations, emergency operation centers and schools. In addition, loss of beds and facility functionality is computed as a function of time for health care facilities.

Output of the essential facilities damage module can be obtained by using the **Results|Essential Facilities** menu. As with the general building stock, results are provided in a tabular format or in a map form. An example of the functionality of health care facilities is found in Figure 10.11. To thematically map a given value, select its column by clicking on the header, and then clicking **Map**. Click on **Return|Return to Table** to go back to the dialog that displays tabular results.

Table 10.4 Direct Physical Damage Outputs - Essential Facilities

Facility Type	Description of Output	Measure
Health Care Facilities	**HAZUS** determines the damage state probabilities for each health care facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements. The expected reduction in available beds for each facility is also determined.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Loss of Beds and Facility Functionality
Police/Fire Stations Emergency Operations Centers Schools	**HAZUS** determines the damage state probabilities for each facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Functionality at Day 1

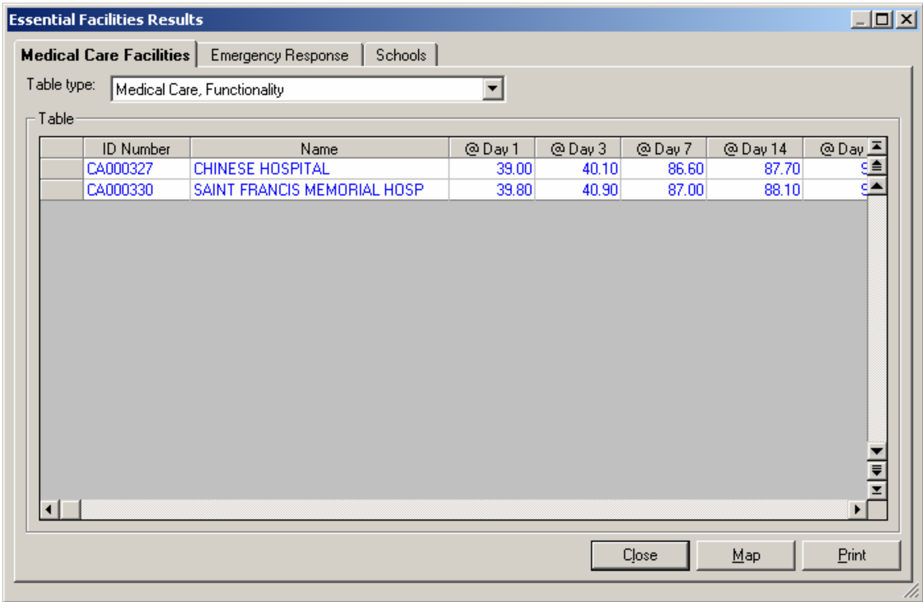


Figure 10.11 Functionality of health care facilities.

10.6 High Potential Loss Facilities

High potential loss facilities tend to be unique and complex facilities that would require in-depth evaluation by structural and geotechnical engineers to assess their vulnerability to earthquakes. These types of facilities are often designed to codes and standards that exceed those for general building stock. Thus, the vulnerability curves that are used for general building stock may be inappropriate for high potential loss facilities. It is likely that the user/engineer will need to define vulnerability curves that are specific to these facilities. Furthermore, often the owners of these facilities have already performed in-depth, site-specific seismic hazard analyses.

For these reasons, **HAZUS** is limited to providing information concerning the location of the study region's high potential loss facilities (see Table 10.5). This can serve as a first step in developing mitigation and preparedness efforts. You may opt to perform a vulnerability analysis of a specific facility, and include the results of the special study with the results of the methodology. Locations of the high potential loss facilities and details about them are found in the **Inventory|High Potential Loss Facilities** menu. Results for military facilities are obtained through the **Results|Military Installations** menu.

Table 10.5 Direct physical damage outputs - high potential loss facilities

Component	Description of Output	Measure
Dams	**HAZUS** provides the locations of dams in the study region.	List of and locations of dams
Nuclear Facilities	**HAZUS** provides the locations of nuclear power facilities in the study region.	List of and locations of nuclear power facilities
Military facilities	**HAZUS** determines the damage state probabilities for each facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities

10.7 Direct Physical Damage - Lifelines

Lifeline systems are vital to the functionality of a community. Damage to these systems after an earthquake can be devastating in terms of the health and safety of the citizens. After the Great Hanshin earthquake in 1995, the water supply system was so severely damaged that people had to rely on trucked-in water. Damage to railway and road systems prevented emergency response personnel from bringing food, water and other supplies into the region. Over 900,000 households were without electricity and 800,000 households without gas in the middle of winter. Damage to roads and blockages of roads due to collapsed buildings prevented police, fire fighters and rescuers from fighting fires and attending to the trapped and injured.

Losses to the community that result from damage to lifelines can be much greater than the costs of repairing the systems. For example, damage to the Kobe harbor, one of the busiest in Japan, stopped the import and export of materials that were essential to the operation of many manufacturing plants in Japan. Factories were forced to close down for lack of materials. Recovery of the region will depend to a great degree on how quickly lifelines can be restored to full functionality. Therefore, assessment of the vulnerability of lifeline systems is a very important part of developing regional emergency preparedness and response plans.

In **HAZUS**, damage to lifeline systems is described in terms of damage to components. Detailed systems analyses are not performed, although simplified system analyses are performed for water systems and electric power. Damage is reported in terms of the probability of reaching or exceeding a specified level of damage when subjected to a given level of ground motion or permanent ground deformation. Associated with each damage state is a restoration curve that is used to evaluate the time required to bring the system back to full functionality.

A probability of functionality is defined as the probability, given an initial level of damage after the earthquake, of the component operating at a certain capacity after a specified period of time. For example, a highway bridge might be found to have the following probabilities of damage, based upon experiencing 0.6g peak ground acceleration and 12 inches of permanent ground deformation.

No damage	3% chance
Slight damage	9% chance
Moderate damage	20% chance
Extensive damage	44% chance
Complete damage	24% chance

Based upon this estimate of damage, the expected functionality of the bridge would be:

14% functional after one day,
26% functional after 3-days,
34% functional after 7 days,
39% functional after 30 days, and
60% functional after a 3-month restoration period.

Another interpretation of these results is that after one day, 14% of the bridges of this type would be functional and after 3 months, 60% of these bridges would be functional. Interdependency of the components on overall transportation system functionality is not addressed by the methodology. Lifelines are divided into transportation systems and utility systems. Table 10.6 summarizes the outputs for each of the seven transportation lifeline systems.

Table 10.6 Direct Physical Damage Outputs - Transportation Systems

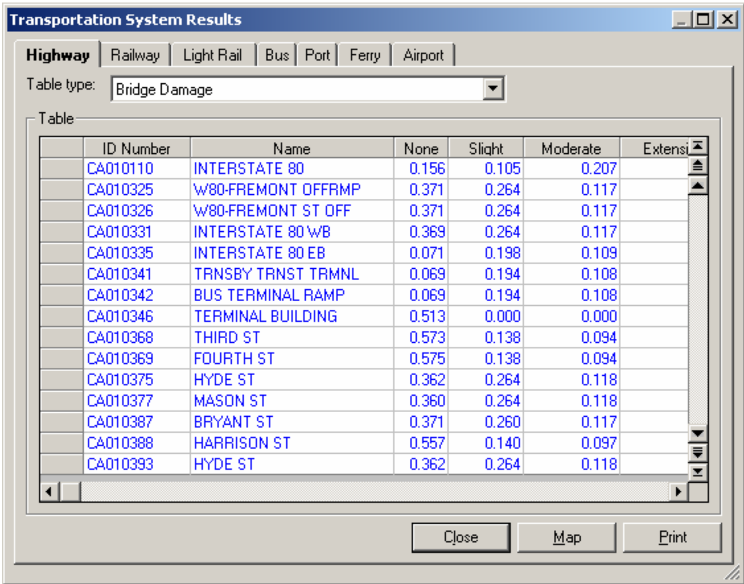
System	Description of Output	Measure
Highway System Railway System Light Rail Bus Ferry Port Airport	a) **HAZUS** determines the damage state probability for each transportation system component in the study region. b) **HAZUS** determines the probability of functionality for each transportation system component at discrete time intervals.	a) System Damage State Probabilities b) Probability of System Functionality

Table 10.7 summarizes the outputs of **HAZUS** for the study region's utility system components. A simplified system analysis is performed for potable water systems and electric power systems. These analyses make simplified assumptions about the serviceability of the systems based on the number of pipe leaks and breaks, or the functionality of medium voltage substations.

Table 10.7 Direct Physical Damage Outputs - Utility Systems

System	Description of Output	Measure
Potable Water	a) **HAZUS** determines the damage state probabilities for each potable water component in the study region. b) **HAZUS** determines the probability of functionality for each potable water component at discrete time intervals. c) **HAZUS** supports simplified potable water system analysis for the study region.	a) System Damage State Probabilities b) System Probability of Functionality c) # of Households without water
Waste Water Natural Gas Oil Pipeline: Crude and Refined Communication	a) **HAZUS** determines the damage state probabilities for each system component in the study region. b) **HAZUS** determines the probability of functionality for each system component at discrete time intervals.	a) System Damage State Probabilities b) System Probability of Functionality
Electric Power	a) **HAZUS** determines the damage state probabilities for each electric power component in the study region. b) **HAZUS** determines the probability of functionality for each electric power component at discrete time intervals. c) **HAZUS** supports simplified system analysis for the study region.	a) System Damage State Probabilities b) System Probability of Functionality c) # of Households without power

Lifeline damage can be viewed in terms of damage states (condition) or functionality, and can be displayed in a tabular or map format. Figure 10.12 shows a table of the damage to highway bridges for the study region. For each of the bridges in the study region (identified by ID number), the probability of being in one of the five damage states is tabulated. For highway bridge id ca010110, the probability of no damage is 0.068 (almost 7%), slight damage is 0.064, and moderate damage is 0.157. This information can be mapped, as shown in Figure 10.13, by clicking on the **Map** button. Each airport facility is identified by a symbol. The shape (or color) of the symbol is associated with a range of probabilities. Users familiar with ArcGIS, have the option of zooming in on any area and viewing that area more closely as shown in Figure 10.14.



ID Number	Name	None	Slight	Moderate	Extensi
CA010110	INTERSTATE 80	0.156	0.105	0.207	
CA010325	W80-FREMONT OFFRMP	0.371	0.264	0.117	
CA010326	W80-FREMONT ST OFF	0.371	0.264	0.117	
CA010331	INTERSTATE 80 WB	0.369	0.264	0.117	
CA010335	INTERSTATE 80 EB	0.071	0.198	0.109	
CA010341	TRNSBY TRNST TRMNL	0.069	0.194	0.108	
CA010342	BUS TERMINAL RAMP	0.069	0.194	0.108	
CA010346	TERMINAL BUILDING	0.513	0.000	0.000	
CA010368	THIRD ST	0.573	0.138	0.094	
CA010369	FOURTH ST	0.575	0.138	0.094	
CA010375	HYDE ST	0.362	0.264	0.118	
CA010377	MASON ST	0.360	0.264	0.118	
CA010387	BRYANT ST	0.371	0.260	0.117	
CA010388	HARRISON ST	0.557	0.140	0.097	
CA010393	HYDE ST	0.362	0.264	0.118	

Figure 10.12 Lifeline outputs: damage to highway bridges.

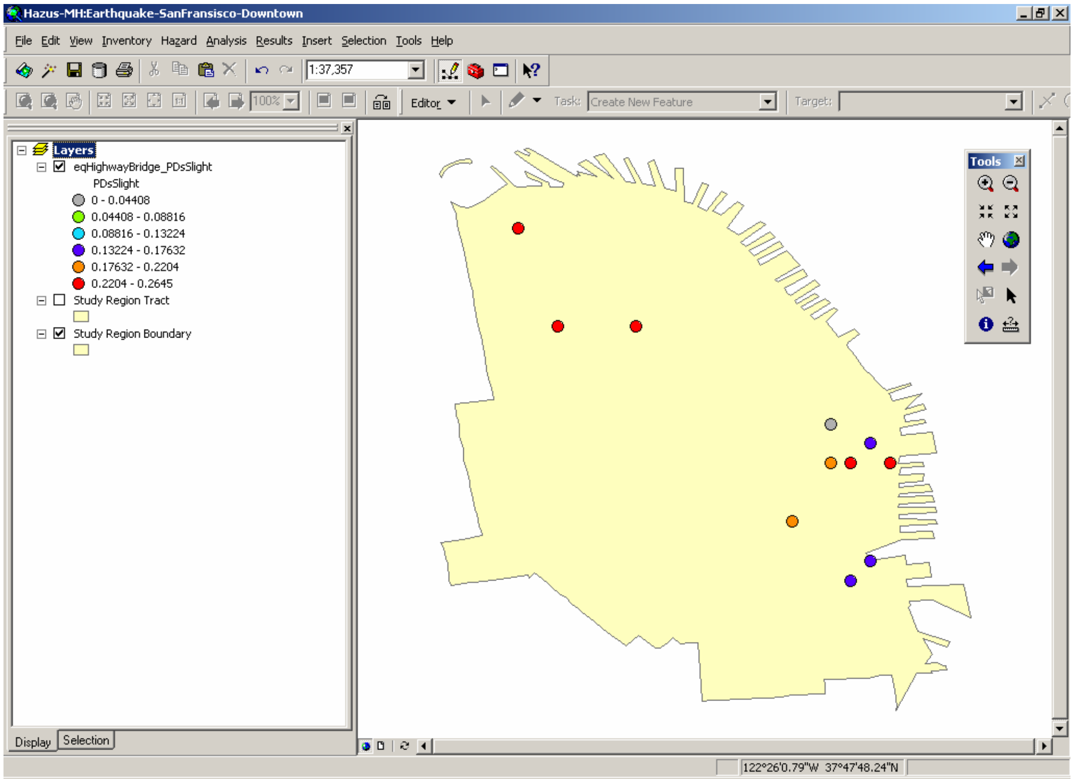


Figure 10.13 Lifeline outputs: map of probability of slight damage to highway bridges for entire study region.

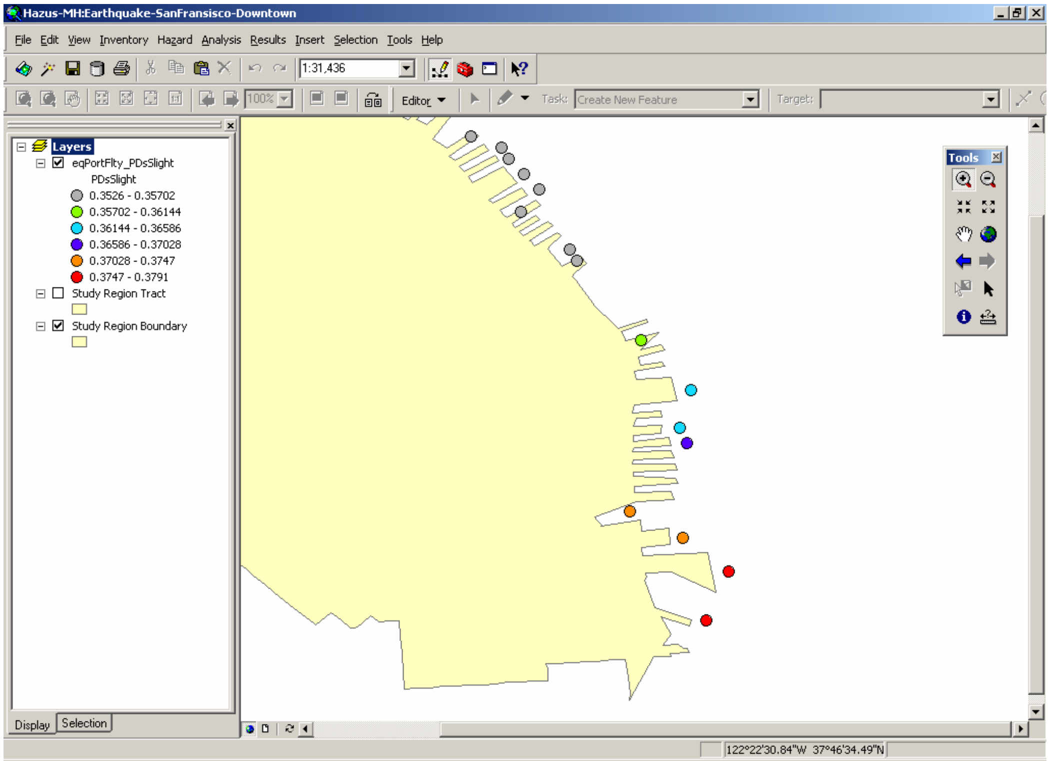


Figure 10.14 Map of probability of slight damage to port facilities for a portion of the study region.

Figure 10.15 shows a table of the functionality of highway bridges at specified periods after the occurrence of the scenario earthquake. According to this table, facility the first bridge would be functional with a 17% probability immediately after the earthquake and functional with a 30% probability after 14 days. Functionality can be mapped by clicking on the **<u>M</u>ap** button. Facilities are mapped as “operational” or “non-operational”. The user must specify a “confidence level” above which the facility is considered operational. In Figure 10.16 the “confidence level” is chosen to be 75%, indicating that if the probability of functionality is greater than 75%, the facility will be considered operational. Based on this definition of operational, many of the airport terminals near the epicenter will be non-operational the day after the earthquake.

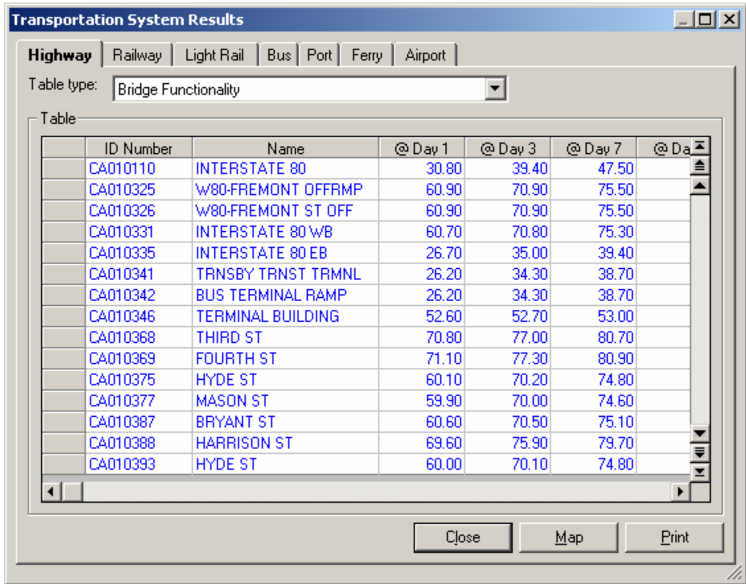


Figure 10.15 Lifeline outputs: functionality of highway bridges reported by number of days since the occurrence of the earthquake.

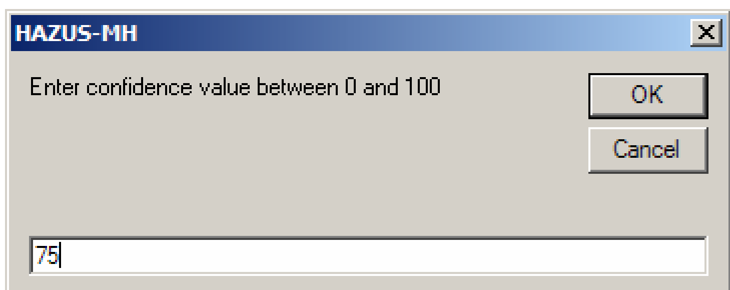


Figure 10.16 Functionality confidence level.

10.8 Induced Physical Damage - Inundation

HAZUS includes earthquake-related flooding information helpful in design of programs to reduce the likelihood of dam or levee failure; and to prepare for those floods that may occur. Development of inundation maps requires an understanding of the downstream topography and requires the involvement of an experienced hydrologist. In the case of tsunamis, inundation models are complex, and are in many cases still in the development stage; therefore, **HAZUS** does not produce inundation maps.

Instead, as a first step in assessing the risk to a study region, all dams and levees are identified. The existing national inventory of dams that is provided with the software includes a hazard classification (low, significant, high) based on the downstream urban development and potential economic loss. The potential for tsunamis and seiches must be assessed by the user outside of **HAZUS** without any estimate of size or consequence. Table 10.8 summarizes the outputs that are available from **HAZUS**.

Table 10.8 Induced Physical Damage Outputs - Inundation

Component	Description of Output	Measure
Tsunami	a) The methodology provides rules to determine if tsunamis are a threat to the study region. b) The user can import existing tsunami inundation maps and overlay with population and economic value maps.	a) Qualify Potential Threat b) Exposed Population Exposed Value ($1,000)
Seiche	a) The methodology provides rules to determine if seiches are a threat on any body of water in the study region. b) The user can import existing seiche inundation maps and overlay with population and economic value maps.	a) Qualify Potential Threat b) Exposed Population Exposed Value ($)
Dam Failure	a) **HAZUS** displays the location of all dams in the study region and (for the default database) ranks the potential impact of the dam failure. b) The user can import existing dam failure inundation maps and overlay with population and economic value maps.	a) List and Locations of Dams and Quantification of Potential Hazard b) Exposed Population Exposed Value ($)
Levee Failure	a) **HAZUS** displays the location of the levees in the study region. b) The user can import existing levee failure inundation maps and overlay with population and economic value maps.	a) List and Locations of Levees b) Exposed Population Exposed Value ($)

For all four types of inundation, **HAZUS** has the ability to import existing inundation maps. These can then be overlaid with population density maps or maps of inventory to estimate exposed population and exposed inventory. The output of the inundation module is a display of the inundation maps that were specified in the data maps dialog as shown in Figure 10.17.

Alternatively, you can view a table of population, value and area exposure by census tract using the **Results|Inundation** menu (see Figure 10.18). This output is only available if an inundation map has been specified. Highlighting the appropriate column and clicking on the Map button can map any one of the outputs.

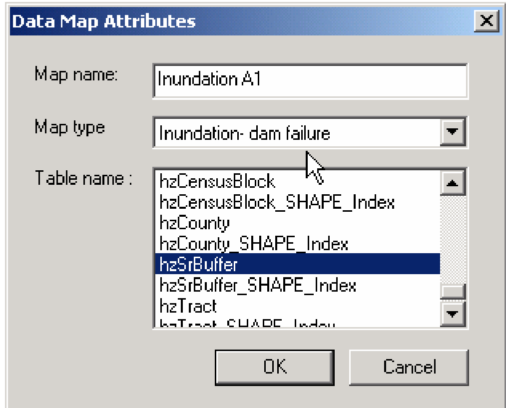


Figure 10.17 Specifying inundation maps.

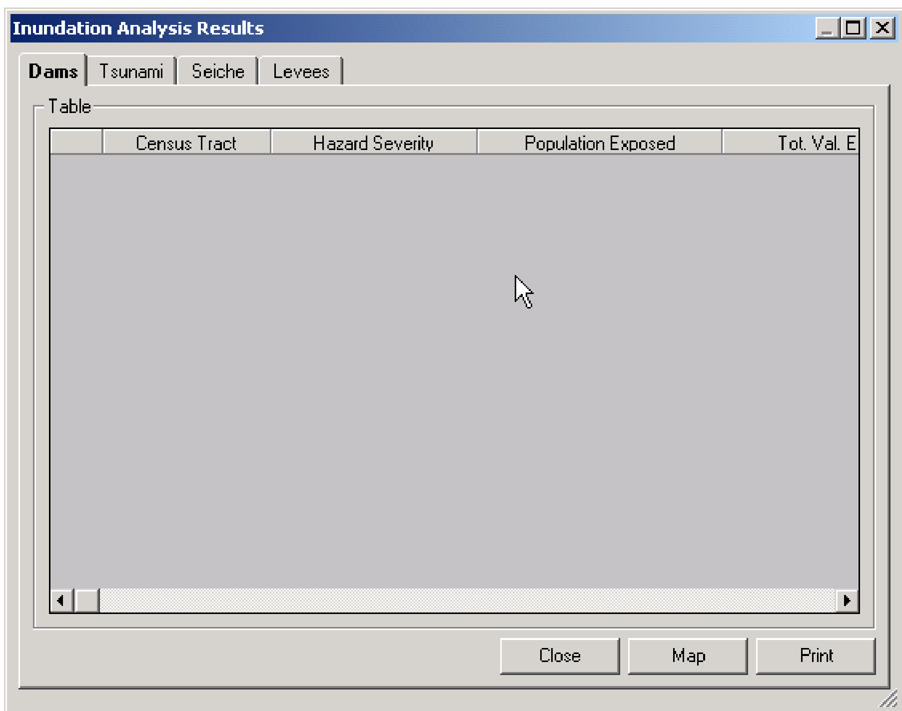


Figure 10.18 Tabulation of exposed population, value and area resulting from inundation map.

10.9 Induced Physical Damage – Hazardous Material Release

Assessment of the consequences of a hazardous materials release requires an understanding of the amounts and types of materials that are released as well as, in some cases, a model of a gaseous plume. A single facility may house many toxic and hazardous materials. Without visiting a facility, assessing the vulnerability of the structure and auditing how materials are stored, it is impossible to give a meaningful estimate of risk. Therefore **HAZUS** does not perform any analysis on hazardous.

Locations of hazardous materials facilities can be mapped and overlaid with ground motion, population and inventory maps. This can provide a preliminary assessment of consequences, which can then be followed up with detailed site-specific studies. In addition, the hazardous facility database can be sorted in a variety of ways allowing the user to view only certain types of materials, facilities with large amounts, highly vulnerable facilities, etc. Table 10.9 summarizes the information available on hazardous materials.

Table 10.9 Induced Physical Damage - Hazardous Material Release

Component	Description	Measure
Hazardous Materials Facilities	a) **HAZUS** provides the location of the hazardous material facilities located in the study region. b) **HAZUS** provides the types and amounts of hazardous materials stored at each location and the health hazard associated with each chemical. c) The user can overlay a map of hazardous material facilities with ground shaking, population, and economic value maps to interrogate the consequences of release at a particular site.	a) List of and Locations of Facilities Containing Hazardous Materials b) Type/Amount of Material Stored at Each Facility

The inventory is the available information on hazardous materials. It can be accessed using the **Inventory|Hazardous Materials** menu. From the Hazardous Material database you can get a listing of the materials and plot site locations as shown in Figures 10.19 and 10.20. Clicking the **Map** button at the bottom of Figure 10.19 generated the output shown in Figure 10.20. The information in the small box at the left-hand side of Figure 10.20 was retrieved using the information tool (**i**) from the ArcMap button toolbar. By using the information tool and clicking on any one of the sites, you can access all of the stored data for that site.

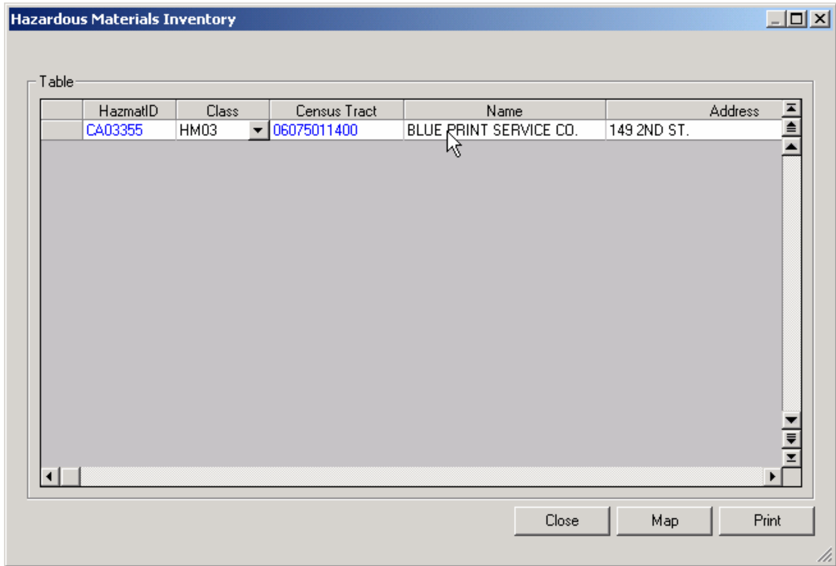


Figure 10.19 Default hazardous material database.

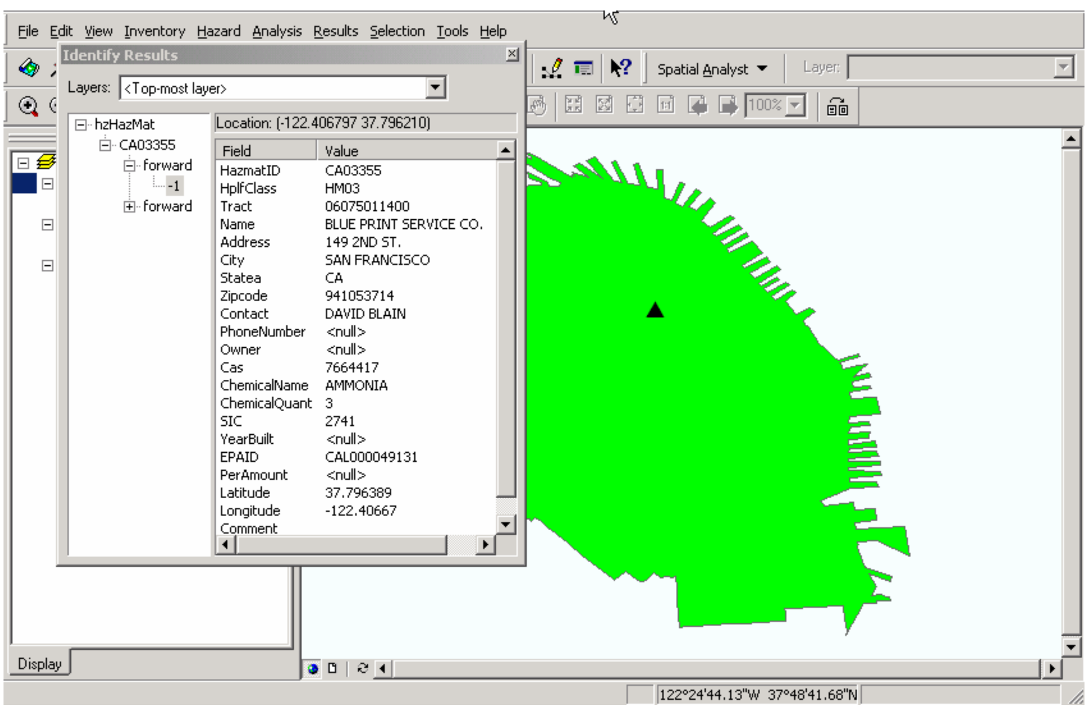


Figure 10.20 Map of default hazardous materials database

10.10 Induced Physical Damage – Fire Following Earthquake

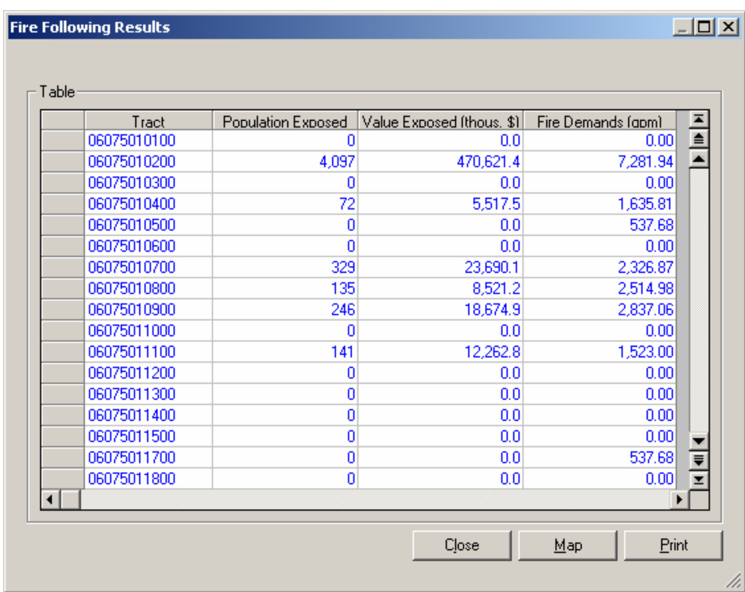
A complete Fire Following Earthquake Model requires extensive input including the types and density of fuel, the number of fire fighting apparatus, the functionality of the water system, the occurrence of hazardous materials releases, wind conditions, and others. To simplify the input, **HAZUS** limits the analysis to an estimate of the number of ignitions, an estimate of the size of the potential burned area, and estimates of exposed population and exposed inventory.

Table 10.10 Induced Physical Damage Module Outputs - Fire Following Earthquake

Component	Description of Output	Measure
Ignition	a) **HAZUS** determines the expected number of fire ignitions by census tract for the study region.	a) Number of ignitions
Burned Area	a) **HAZUS** determines the expected burned area by census tract for the study region. b) Expected burned area is combined with population and economic value to estimate exposed population and inventory.	a) Percentage of Burned Area b) Exposed Population Exposed Value ($)

The outputs from Fire Following Earthquake Model are presented in **HAZUS** in a table as shown in Figure 10.21. For each census tract in the study region, the following values are displayed:

- Best estimates of the percent of the census tract that has been burned
- Standard deviation of the estimate of percent of burned area
- Number of ignitions in the census tract
- The population in the census tract that is exposed to fire (% burned area X total population in census tract)
- The value of inventory (in dollars) in the census tract fire exposed to fire (% burned area X total building value in census tract)



Tract	Population Exposed	Value Exposed (thous. $)	Fire Demands (gpm)
06075010100	0	0.0	0.00
06075010200	4,097	470,621.4	7,281.94
06075010300	0	0.0	0.00
06075010400	72	5,517.5	1,635.81
06075010500	0	0.0	537.68
06075010600	0	0.0	0.00
06075010700	329	23,690.1	2,326.87
06075010800	135	8,521.2	2,514.98
06075010900	246	18,674.9	2,837.06
06075011000	0	0.0	0.00
06075011100	141	12,262.8	1,523.00
06075011200	0	0.0	0.00
06075011300	0	0.0	0.00
06075011400	0	0.0	0.00
06075011500	0	0.0	0.00
06075011700	0	0.0	537.68
06075011800	0	0.0	0.00

Figure 10.21 Output of fire following earthquake module.

Highlighting the column and then clicking on the Map button will map any of the columns in Figure 10.21. The "Fire Demand (gpm)" column has been mapped in Figure 10.22. A summary report of the output of the Fire Following Earthquake Model can also be printed to the screen or to a printer.

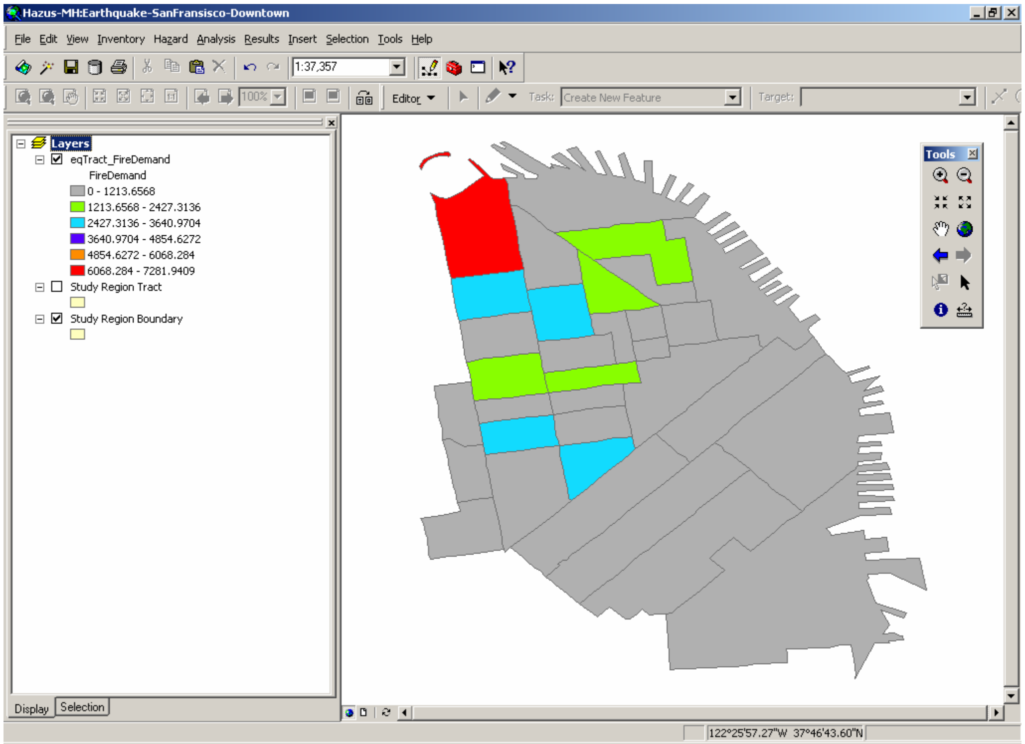


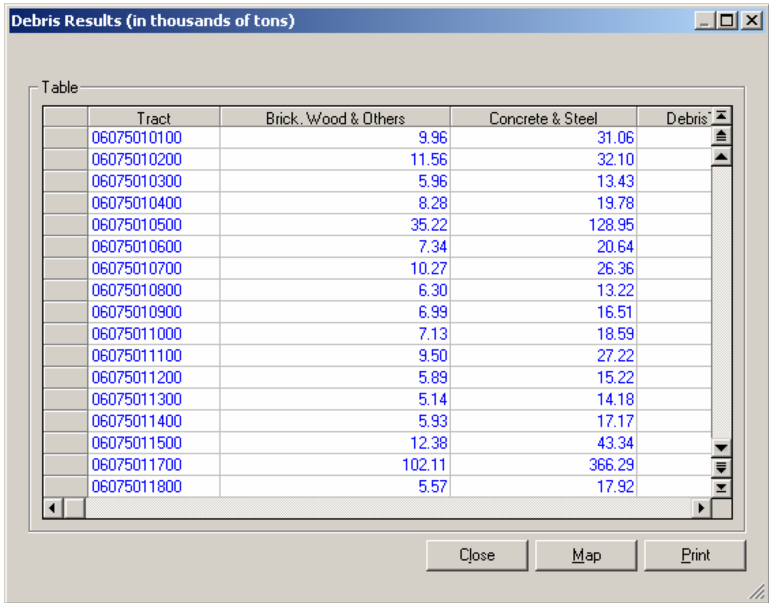
Figure 10.22 Map of fire demand for each census tract.

HAZUS provides information about the debris generated during the seismic event to enable users to prepare and to rapidly and efficiently manage debris removal and disposal. As shown in Table 10.11, two types of debris are identified: (1) reinforced concrete and steel that requires special equipment to break it up before it can be transported, and (2) brick, wood and other debris that can be loaded directly onto trucks with bulldozers. For each census tract, **HAZUS** determines the amount of debris of each type that is generated.

Table 10.11 Induced Physical Damage Module Outputs - Debris

Component	Description of Output	Measure
Brick, Wood & Others	a) **HAZUS** determines the expected amount of brick, wood, and other debris generated in each census tract of the study region.	a) Weight of Debris Generated
Reinforced Concrete & Steel	a) **HAZUS** determines the expected amount of reinforced concrete and steel debris generated in each census tract of the study region.	a) Weight of Debris Generated

In **HAZUS,** debris results will appear as a table, as shown in Figure 10.23, that can be printed to the screen or the printer. In addition, you will be able to map by census tract the weight of generated debris using the **Map** button, as shown in Figure 10.24.


Debris Results (in thousands of tons)

Table

Tract	Brick, Wood & Others	Concrete & Steel	Debris
06075010100	9.96	31.06	
06075010200	11.56	32.10	
06075010300	5.96	13.43	
06075010400	8.28	19.78	
06075010500	35.22	128.95	
06075010600	7.34	20.64	
06075010700	10.27	26.36	
06075010800	6.30	13.22	
06075010900	6.99	16.51	
06075011000	7.13	18.59	
06075011100	9.50	27.22	
06075011200	5.89	15.22	
06075011300	5.14	14.18	
06075011400	5.93	17.17	
06075011500	12.38	43.34	
06075011700	102.11	366.29	
06075011800	5.57	17.92	

Close Map Print

Figure 10.23 Output of the debris module in thousands of tons per census tract.

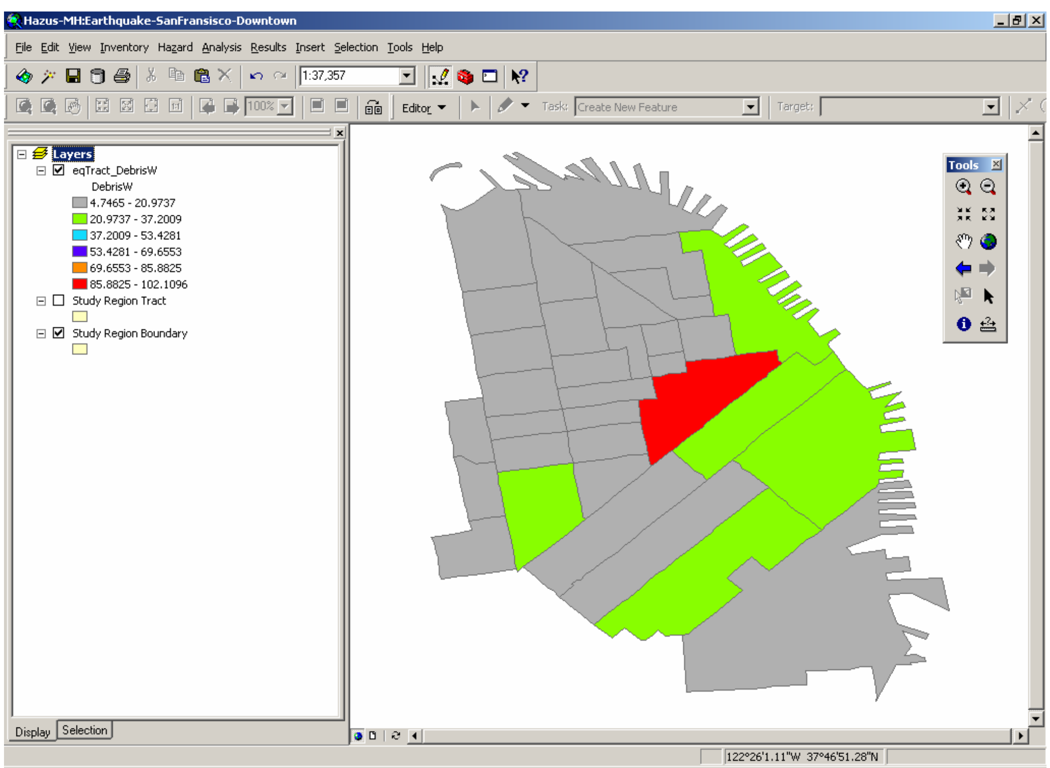


Figure 10.24 Weight of generated wood debris by census tract.

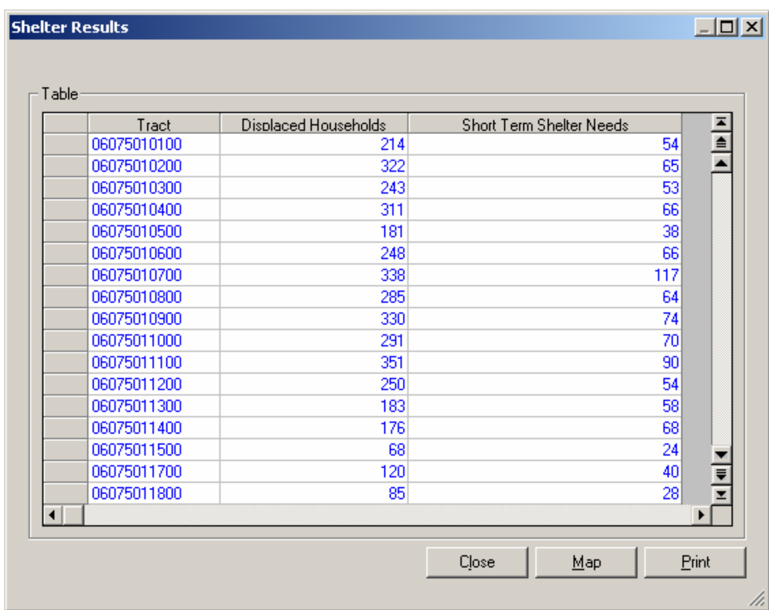
10.11 Direct Economic and Social Losses

HAZUS provides information concerning the estimated number of displaced households and persons requiring temporary shelter to enable the design of programs to temporarily shelter victims.

Table 10.11 Direct Economic and Social Losses Module Outputs - Shelter

Component	Description of Output	Measure
Displaced Households	a) **HAZUS** determines the expected number of displaced households by census tract in the study region.	a) Number of Displaced Households
Temporary Shelter	a) **HAZUS** determines the expected number of people requiring temporary shelter by census tract in the study region.	a) Number of People Requiring Temporary Shelter

The total number of displaced households for each census tract of the study region is one output of the shelter module. The number of displaced households is used to estimate the short-term shelter needs. Short-term shelter needs are reported in the number of people needing public shelter. The results, as displayed in Figure 10.25, are retrieved using the **Results|Shelter** menu. As with all results, these can be thematically mapped by highlighting a column and clicking on the **Map** button.



Tract	Displaced Households	Short Term Shelter Needs
06075010100	214	54
06075010200	322	65
06075010300	243	53
06075010400	311	66
06075010500	181	38
06075010600	248	66
06075010700	338	117
06075010800	285	64
06075010900	330	74
06075011000	291	70
06075011100	351	90
06075011200	250	54
06075011300	183	58
06075011400	176	68
06075011500	68	24
06075011700	120	40
06075011800	85	28

Figure 10.25 Output of shelter module.

The output of the casualty module is summarized in Table 10.12.

Table 10.12 Direct Economic and Social Losses Module Outputs - Casualties

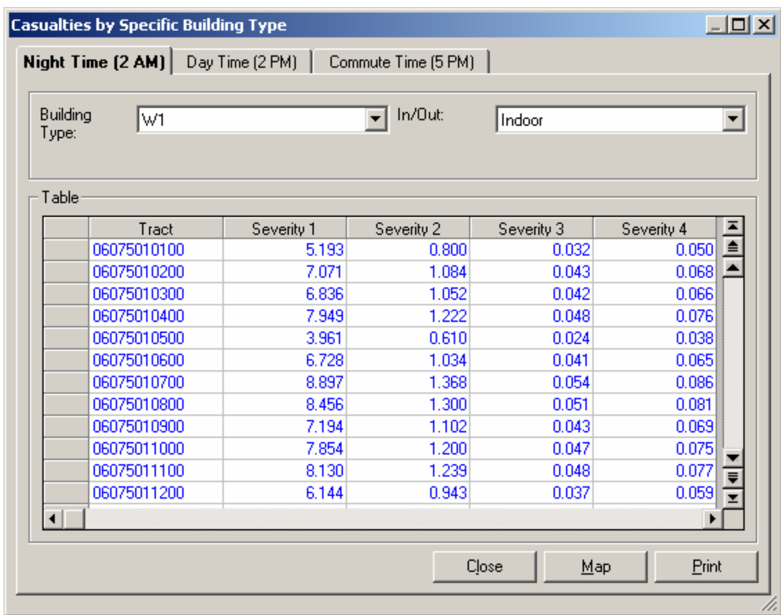
Component	Description of Output	Measure
Casualties	a) **HAZUS** determines the expected number of casualties for each casualty severity (medical aid,	a) Number of casualties for each of

	hospital treatment, life-threatening, death) by census tract for the study region.	the four severities

For each census tract, the following results (use **Results|Casualties** menu) are provided at three times of day (2 AM, 2 PM and 5 PM) by occupancy type or by building type.

- Single family dwellings (RES1) casualties (severity 1, 2, 3 and 4)
- Residential (other than RES1) casualties (severity 1, 2, 3 and 4)
- Commercial casualties (severity 1, 2, 3 and 4)
- Industrial casualties (severity 1, 2, 3 and 4)
- Education casualties (severity 1, 2, 3 and 4)
- Hotel casualties (severity 1, 2, 3 and 4)
- Commuting casualties (severity 1, 2, 3 and 4)
- Total casualties (severity 1, 2, 3 and 4)

As with the other output, highlighting the desired column and clicking on the Map button will map the results.



Tract	Severity 1	Severity 2	Severity 3	Severity 4
06075010100	5.193	0.800	0.032	0.050
06075010200	7.071	1.084	0.043	0.068
06075010300	6.836	1.052	0.042	0.066
06075010400	7.949	1.222	0.048	0.076
06075010500	3.961	0.610	0.024	0.038
06075010600	6.728	1.034	0.041	0.065
06075010700	8.897	1.368	0.054	0.086
06075010800	8.456	1.300	0.051	0.081
06075010900	7.194	1.102	0.043	0.069
06075011000	7.854	1.200	0.047	0.075
06075011100	8.130	1.239	0.048	0.077
06075011200	6.144	0.943	0.037	0.059

Figure 10.26 Output of casualty module showing residential casualties at 2 PM.

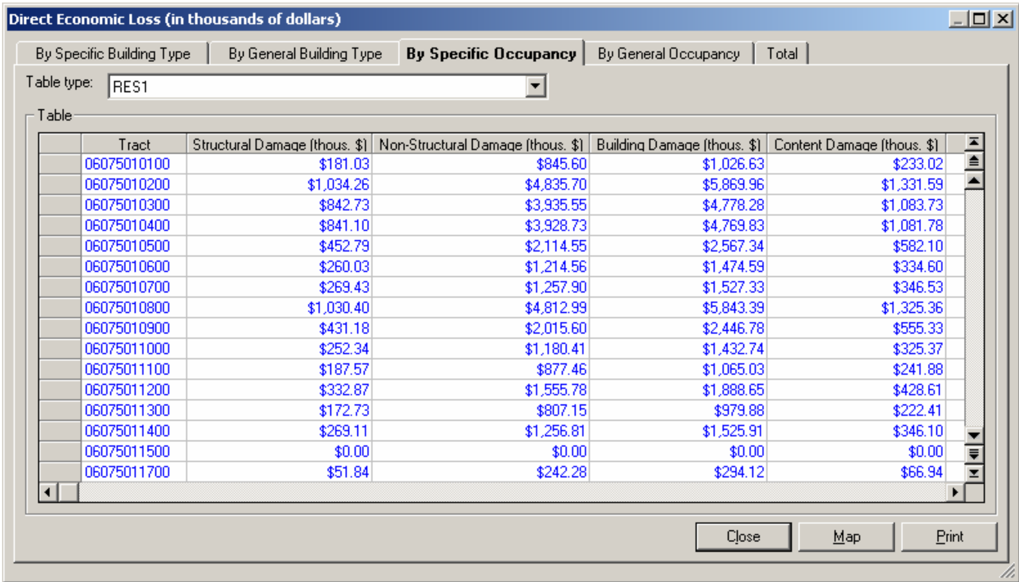
HAZUS provides economic loss information to enable users to motivate policy-makers to consider cost-benefit implication of mitigation activities. All default data for direct economic loss estimates are provided in 1994 dollars. You will need to convert 1994 dollars to those that are valid when you run your study. Losses for lifelines are reported separately from losses for buildings.

Table 10.13 Direct Economic and Social Losses Module Outputs - Direct Economic Loss - Buildings

Component	Description of Output	Measure
Repair and Replacement Costs	a) **HAZUS** determines the expected dollar loss due to the repair and replacement of the general building stock by census tract for the study region.	a) Dollar Loss
Contents Damage	a) **HAZUS** determines the expected dollar loss due to contents damage by census tract for the study region.	a) Dollar Loss
Business Inventory Damage	a) **HAZUS** determines the expected dollar loss due to business inventory damage by census tract for the study region.	a) Dollar Loss
Relocation Costs	a) **HAZUS** determines the expected dollar loss due to business relocation by census tract for the study region.	a) Dollar Loss
Capital-related Income Loss	a) **HAZUS** determines the expected business income loss by census tract for the study region.	a) Dollar Loss
Wage Loss	a) **HAZUS** determines the expected wage loss by census tract for the study region.	a) Dollar Loss
Rental Loss	a) **HAZUS** determines the expected dollar loss due to the repair and replacement of buildings by census tract for the study region.	a) Dollar Loss

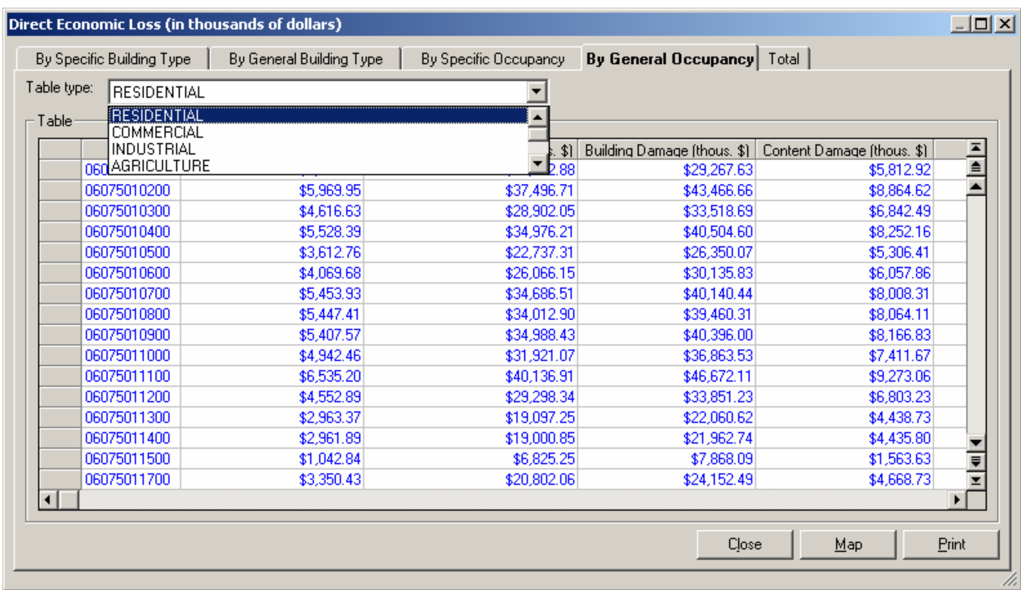
Building loss estimates can be viewed by clicking on the **Results|Buildings Economic Loss** menu. Building losses are summarized in terms of the seven General Occupancy classes (Residential, Commercial, Industrial, Agriculture, Religious, Government and Education), or in terms of the 33 Specific Occupancy Classes. As can be seen in Figure 10.27, the total direct economic losses for each census tract are reported. The total losses include structural and non-structural repair, contents loss, relocation costs, proprietor's income loss and rental loss.

Losses also can be reported by general occupancy. The types reported are structural and non-structural repair, total building costs (the sum of structural and non-structural), contents loss, relocation costs, proprietor's income loss and rental loss. These losses are reported by census tract for each of the seven general occupancy classes as shown in Figure 10.28.



Tract	Structural Damage (thous. $)	Non-Structural Damage (thous. $)	Building Damage (thous. $)	Content Damage (thous. $)
06075010100	$181.03	$845.60	$1,026.63	$233.02
06075010200	$1,034.26	$4,835.70	$5,869.96	$1,331.59
06075010300	$842.73	$3,935.55	$4,778.28	$1,083.73
06075010400	$841.10	$3,928.73	$4,769.83	$1,081.78
06075010500	$452.79	$2,114.55	$2,567.34	$582.10
06075010600	$260.03	$1,214.56	$1,474.59	$334.60
06075010700	$269.43	$1,257.90	$1,527.33	$346.53
06075010800	$1,030.40	$4,812.99	$5,843.39	$1,325.36
06075010900	$431.18	$2,015.60	$2,446.78	$555.33
06075011000	$252.34	$1,180.41	$1,432.74	$325.37
06075011100	$187.57	$877.46	$1,065.03	$241.88
06075011200	$332.87	$1,555.78	$1,888.65	$428.61
06075011300	$172.73	$807.15	$979.88	$222.41
06075011400	$269.11	$1,256.81	$1,525.91	$346.10
06075011500	$0.00	$0.00	$0.00	$0.00
06075011700	$51.84	$242.28	$294.12	$66.94

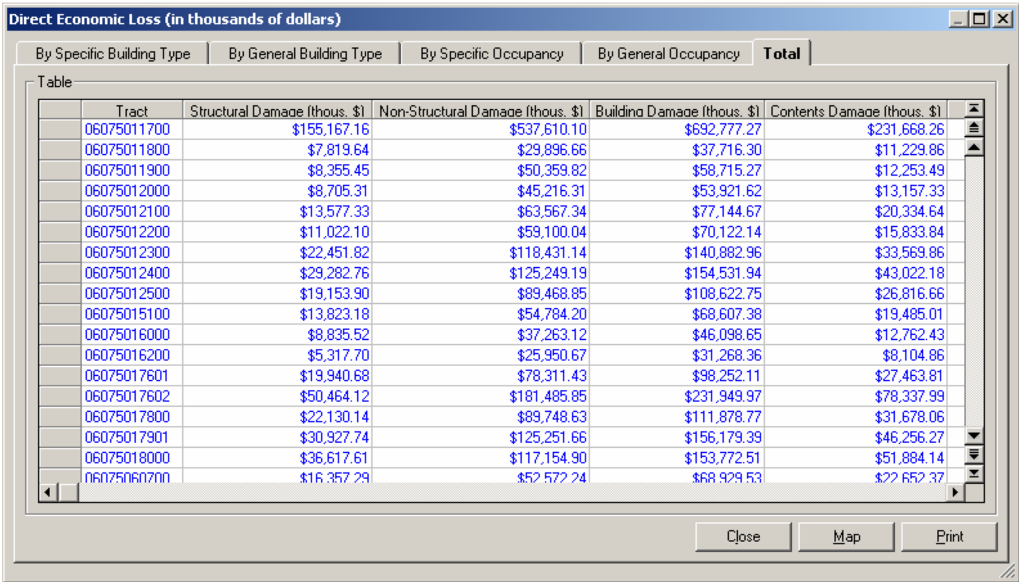
Figure 10.27 Total building losses reported by specific occupancy class



Tract		s. $)	Building Damage (thous. $)	Content Damage (thous. $)
060		2.88	$29,267.63	$5,812.92
06075010200	$5,969.95	$37,496.71	$43,466.66	$8,864.62
06075010300	$4,616.63	$28,902.05	$33,518.69	$6,842.49
06075010400	$5,528.39	$34,976.21	$40,504.60	$8,252.16
06075010500	$3,612.76	$22,737.31	$26,350.07	$5,306.41
06075010600	$4,069.68	$26,066.15	$30,135.83	$6,057.86
06075010700	$5,453.93	$34,686.51	$40,140.44	$8,008.31
06075010800	$5,447.41	$34,012.90	$39,460.31	$8,064.11
06075010900	$5,407.57	$34,988.43	$40,396.00	$8,166.83
06075011000	$4,942.46	$31,921.07	$36,863.53	$7,411.67
06075011100	$6,535.20	$40,136.91	$46,672.11	$9,273.06
06075011200	$4,552.89	$29,298.34	$33,851.23	$6,803.23
06075011300	$2,963.37	$19,097.25	$22,060.62	$4,438.73
06075011400	$2,961.89	$19,000.85	$21,962.74	$4,435.80
06075011500	$1,042.84	$6,825.25	$7,868.09	$1,563.63
06075011700	$3,350.43	$20,802.06	$24,152.49	$4,668.73

Figure 10.28 Types of building losses reported by general occupancy class

The total loss of each type for all economic sectors can be viewed using the window shown in Figure 10.29. This window differs from that shown in Figure 10.28 in that, for example, the total cost of structural damage as reported in Figure 10.29 is the sum of the contents damage for all of the seven general occupancies shown in Figure 10.28.



Direct Economic Loss (in thousands of dollars)

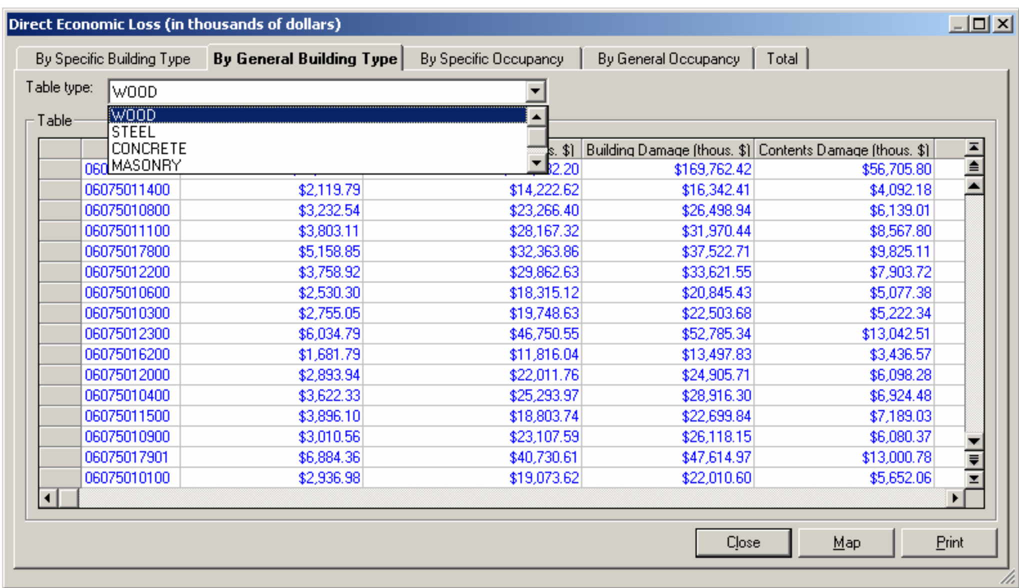
By Specific Building Type | By General Building Type | By Specific Occupancy | By General Occupancy | Total

Table

	Tract	Structural Damage (thous. $)	Non-Structural Damage (thous. $)	Building Damage (thous. $)	Contents Damage (thous. $)
	06075011700	$155,167.16	$537,610.10	$692,777.27	$231,668.26
	06075011800	$7,819.64	$29,896.66	$37,716.30	$11,229.86
	06075011900	$8,355.45	$50,359.82	$58,715.27	$12,253.49
	06075012000	$8,705.31	$45,216.31	$53,921.62	$13,157.33
	06075012100	$13,577.33	$63,567.34	$77,144.67	$20,334.64
	06075012200	$11,022.10	$59,100.04	$70,122.14	$15,833.84
	06075012300	$22,451.82	$118,431.14	$140,882.96	$33,569.86
	06075012400	$29,282.76	$125,249.19	$154,531.94	$43,022.18
	06075012500	$19,153.90	$89,468.85	$108,622.75	$26,816.66
	06075015100	$13,823.18	$54,784.20	$68,607.38	$19,485.01
	06075016000	$8,835.52	$37,263.12	$46,098.65	$12,762.43
	06075016200	$5,317.70	$25,950.67	$31,268.36	$8,104.86
	06075017601	$19,940.68	$78,311.43	$98,252.11	$27,463.81
	06075017602	$50,464.12	$181,485.85	$231,949.97	$78,337.99
	06075017800	$22,130.14	$89,748.63	$111,878.77	$31,678.06
	06075017901	$30,927.74	$125,251.66	$156,179.39	$46,256.27
	06075018000	$36,617.61	$117,154.90	$153,772.51	$51,884.14
	06075060700	$16,357.29	$52,572.24	$68,929.53	$22,652.37

Close | Map | Print

Figure 10.29 Total economic building losses reported by census tract.



Direct Economic Loss (in thousands of dollars)

By Specific Building Type | By General Building Type | By Specific Occupancy | By General Occupancy | Total

Table type: WOOD

WOOD
STEEL
CONCRETE
MASONRY

Table

	Tract		...s. $)	Building Damage (thous. $)	Contents Damage (thous. $)
	060...		...2.20	$169,762.42	$56,705.80
	06075011400	$2,119.79	$14,222.62	$16,342.41	$4,092.18
	06075010800	$3,232.54	$23,266.40	$26,498.94	$6,139.01
	06075011100	$3,803.11	$28,167.32	$31,970.44	$8,567.80
	06075017800	$5,158.85	$32,363.86	$37,522.71	$9,825.11
	06075012200	$3,758.92	$29,862.63	$33,621.55	$7,903.72
	06075010600	$2,530.30	$18,315.12	$20,845.43	$5,077.38
	06075010300	$2,755.05	$19,748.63	$22,503.68	$5,222.34
	06075012300	$6,034.79	$46,750.55	$52,785.34	$13,042.51
	06075016200	$1,681.79	$11,816.04	$13,497.83	$3,436.57
	06075012000	$2,893.94	$22,011.76	$24,905.71	$6,098.28
	06075010400	$3,622.33	$25,293.97	$28,916.30	$6,924.48
	06075011500	$3,896.10	$18,803.74	$22,699.84	$7,189.03
	06075010900	$3,010.56	$23,107.59	$26,118.15	$6,080.37
	06075017901	$6,884.36	$40,730.61	$47,614.97	$13,000.78
	06075010100	$2,936.98	$19,073.62	$22,010.60	$5,652.06

Close | Map | Print

Figure 10.30 Types of building losses reported by general building type

Finally, losses can be reported for each of the 36 specific building classes or the five general building type classes for each census tract as shown in Figure 10.30.

The loss estimates for lifeline systems are summarized in Table 10.14. These are accessed through the **Results|Lifelines Economic Loss** menu.

Table 10.14 Direct economic and social losses module outputs - direct economic loss - lifelines

Component	Description of Output	Measure
Repair and	a) The methodology determines the expected dollar	a) Dollar Loss

Replacement Costs	loss due to the repair and replacement of lifelines components.	

Figure 10.31 shows an example of a results window for transportation systems. Losses are reported for each component of the system, for example, in this window, losses are reported for each highway bridge. You can create similar reports for each type of component and each type of lifeline by clicking on the tabs at the top of Figure 10.31 and using the list box next to the label "Table Type". Like all the other results, the results in Figures 10.31 can also be mapped by clicking on the **Map** button.

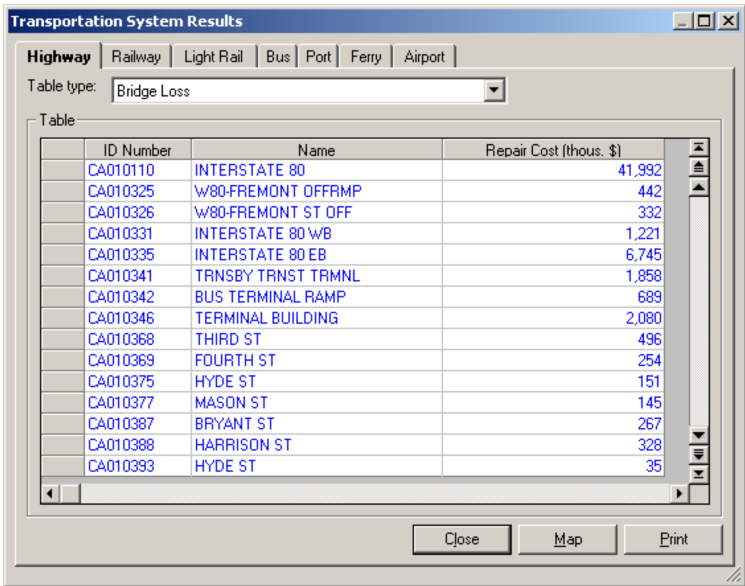


Figure 10.31 Direct economic losses to lifeline components

10.12 Indirect Economic Impacts

HAZUS provides information concerning the indirect economic effects of the scenario event to enable financial institutions and government planners to anticipate losses and develop programs to compensate for them. The indirect economic impact information also enables users to motivate policy-makers to consider cost-benefit implications of mitigation activities.

Table 10.15 Indirect economic impacts module outputs

Component	Description of Output	Measure
Economic Output	a) Indirect output loss as a percentage of original output	Percentage
Employment	a) Indirect employment loss as a percentage of original employment	Percentage
Income	a) Indirect income loss as a percentage of original income	Percentage

10.13 Summary Reports

The options to view summaries of the outputs of each of the **HAZUS** modules are: Inventory, Building Damage, Lifeline Damage, Induced Damage and Losses as shown in the Figure 10.32. You can pick the summary report from any of the windows below and click on the **View** button to generate the report. Sample summary reports of building damage by general occupancy and building stock exposure by building type are shown in Figures 10.33 and 10.34. Additional information in these reports can be viewed by scrolling to the right. Clicking on the print button can print reports.

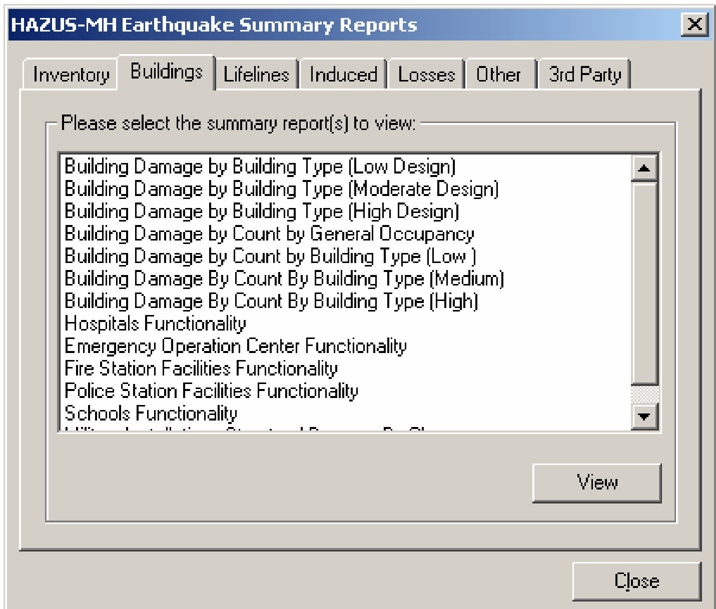
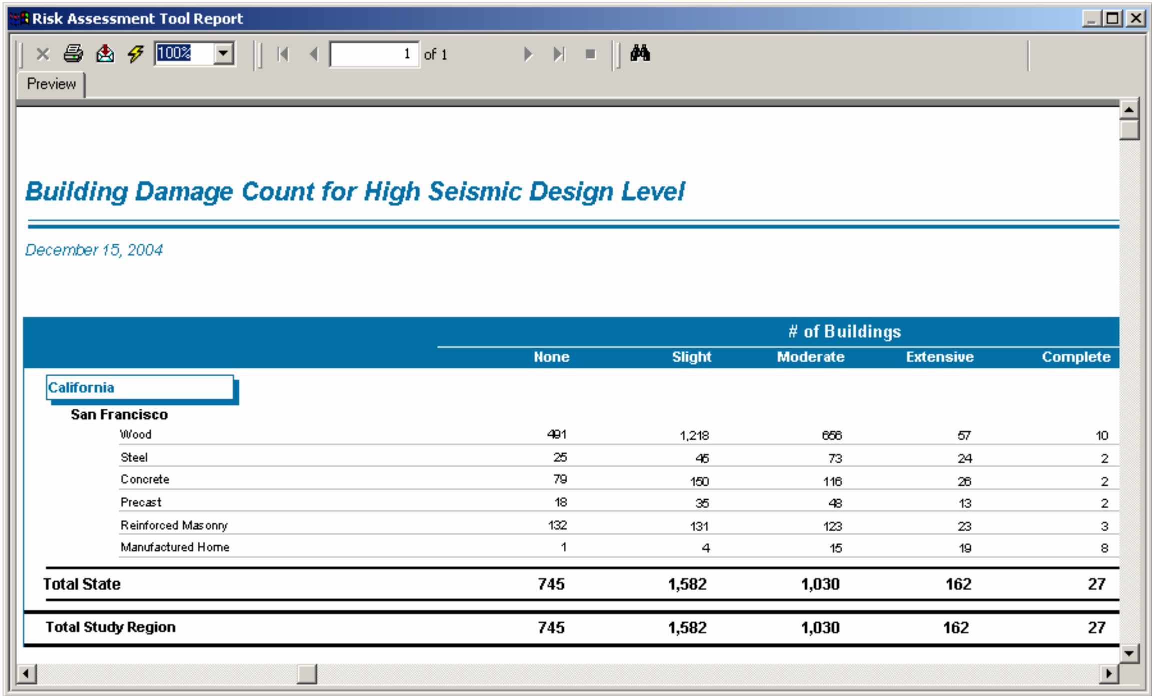
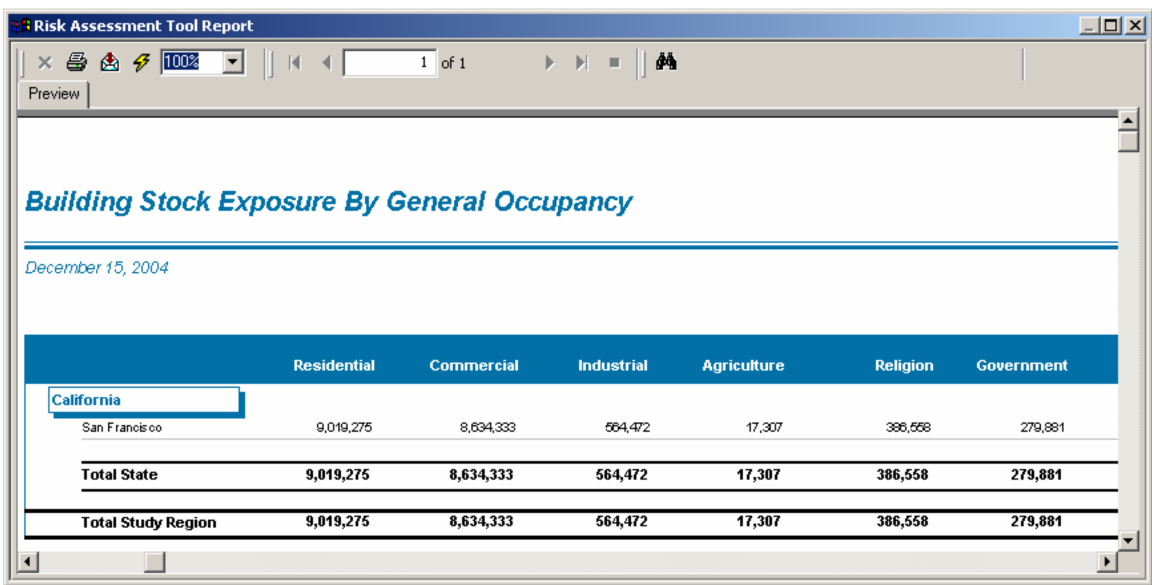


Figure 10.32 Summary report selection window for buildings summary reports.



	# of Buildings				
	None	Slight	Moderate	Extensive	Complete
California					
San Francisco					
Wood	491	1,218	656	57	10
Steel	25	45	73	24	2
Concrete	79	150	116	26	2
Precast	18	35	48	13	2
Reinforced Masonry	132	131	123	23	3
Manufactured Home	1	4	15	19	8
Total State	**745**	**1,582**	**1,030**	**162**	**27**
Total Study Region	**745**	**1,582**	**1,030**	**162**	**27**

Figure 10.33 Sample summary report of building damage count.



	Residential	Commercial	Industrial	Agriculture	Religion	Government
California						
San Francisco	9,019,275	8,634,333	564,472	17,307	386,558	279,881
Total State	**9,019,275**	**8,634,333**	**564,472**	**17,307**	**386,558**	**279,881**
Total Study Region	**9,019,275**	**8,634,333**	**564,472**	**17,307**	**386,558**	**279,881**

Figure 10.34 Sample summary report of building stock exposure by occupancy type.

The 20-page **Global Summary Report** is a comprehensive standardized summary report that provides inventory, hazard and analysis results related to the scenario event. Selecting the **Other** tab as shown in Figure 10.35 will access the window that contains the **Global Summary Report**.

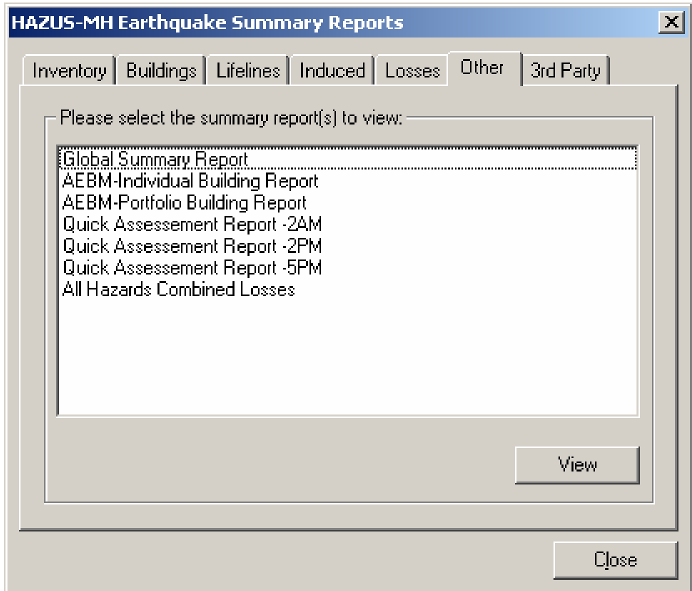


Figure 10.35 The Global Summary report option

The Global Summary Report is organized as follows:

1. **General Description of the Region**
2. **Building and Lifeline Inventory**
   - **2.A Building Inventory**
   - **2.B Critical Facility Inventory**
   - **2.C Transportation and Utility Lifeline Inventory**
3. **Earthquake Scenario Parameters**
4. **Direct Earthquake Damage**
   - **4.A Buildings Damage**
   - **4.B Critical Facilities Damage**
   - **4.C Transportation and Utility Lifeline Damage**
5. **Induced Earthquake Damage**
   - **5.A Fire Following Earthquake**
   - **5.B Debris Generation**
6. **Social Impact**
   - **6.A Shelter Requirements**
   - **6.B Casualties**
7. **Economic Loss**
   - **7.A Building Losses**
   - **7.B Transportation and Utility Lifeline Losses**
   - **7.C Long-term Indirect Economic Impacts**

The **All Hazards Combined Losses** summary report can be viewed if you have run an annualized loss analysis for all three hazards (earthquake, flood, and hurricane). The report will calcule the combined losses for the given multi-hazard region.

Chapter 11. References

Note to users: Many of these references are difficult to find. However, most of them can be obtained from the libraries maintained at the National Center for Earthquake Engineering Research at Buffalo, the Earthquake Engineering Research Center at the University of California, Berkeley, the National Hazards Research and Applications Center of the University of Colorado and the Natural Hazards Research Program of the American Institue of Architectrual Research, AIA/ACSA in Washington D.C.. Publications by Applied Technology Council, Association of Bay Area Governments, the Federal Emergency Management Agency, US Geological Survey, US Census Bureau and other government agencies can be obtained directly from these organizations.

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Appendix A. Installation Verification Document

A.1 Introduction

A.1.1 Purpose

The goal of the document is to show that the HAZUS-MH MR3 product can successfully generate results immediately following product installation.

This document provides a step-by-step procedure that should enable a user to start with a successfully installed HAZUS-MH MR3 product and end up with a summary report.

A.1.2 Scope

This document discusses only the Earthquake model steps required to generate an initial set of results. It does not address installation or any of the other hazards. The study region of interest is San Francisco County, California.

A.1.3 Timing

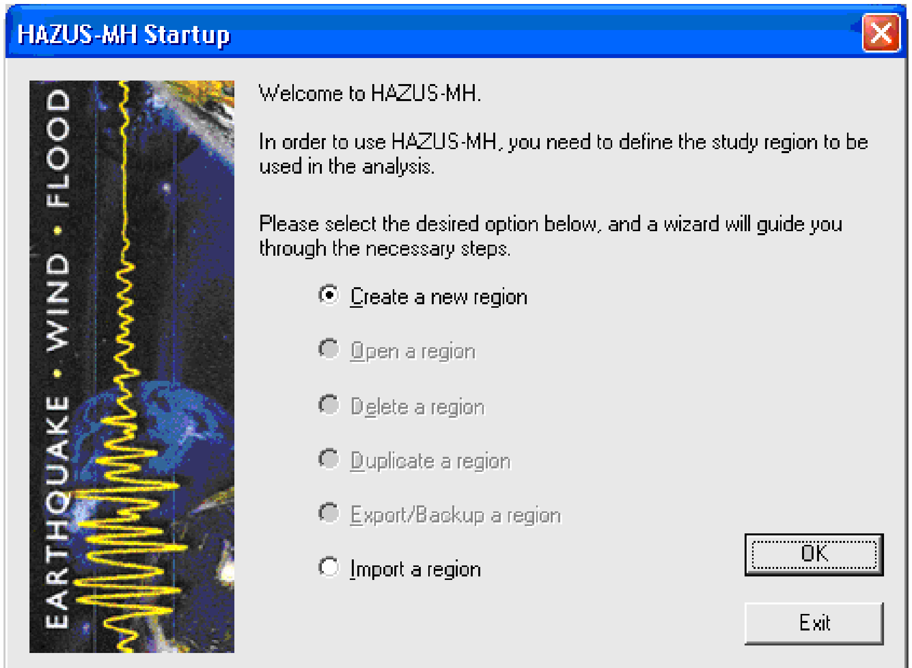
For reference, in some steps it will say that the step should take between (as example) 3 and 5 minutes. This is to give you an idea of what to expect. The timing is based on a 1.4 GHz PC with 512MB of RAM. Faster or slower computers will vary accordingly.

A.2 Study Region Creation Verification Procedure

This section assumes HAZUS-MH has been successfully installed. The following steps will demonstrate that an earthquake study region can be created.

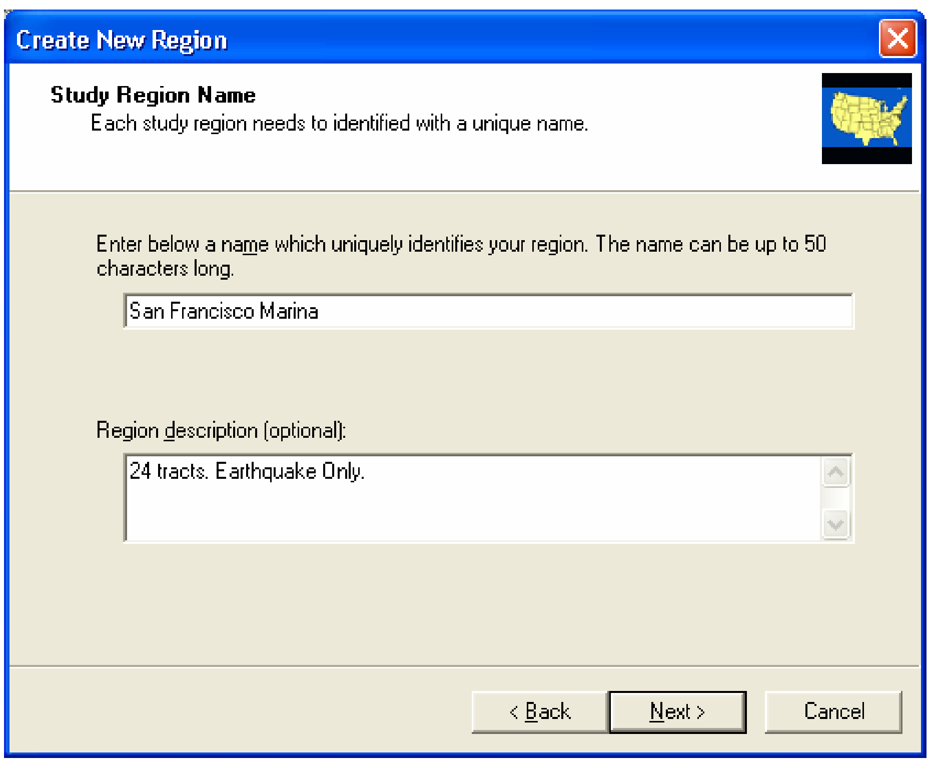
A.2.1 Select “Create a new region”

Start HAZUS-MH. Use the region wizard to create a new study region.

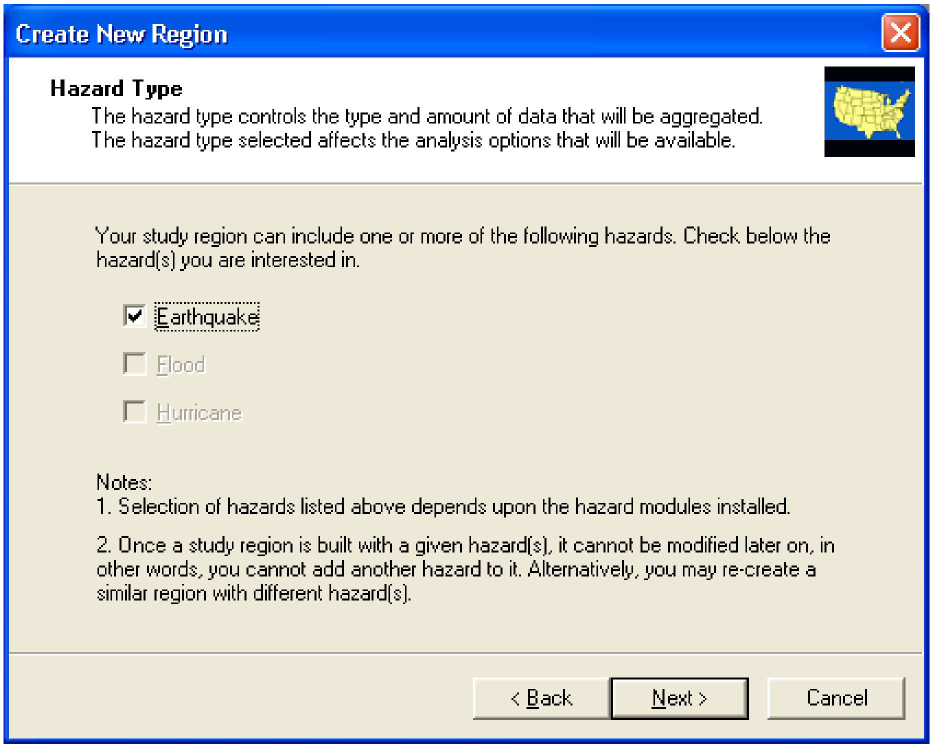


A.2.2 Enter a Name

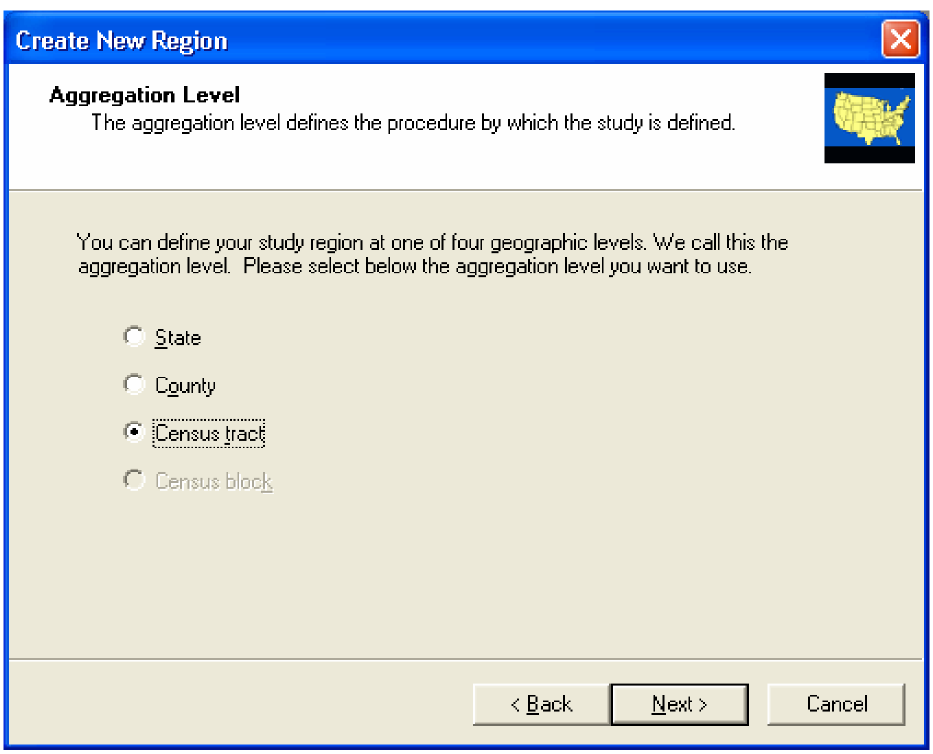
Enter a unique name for the study region, as shown below.



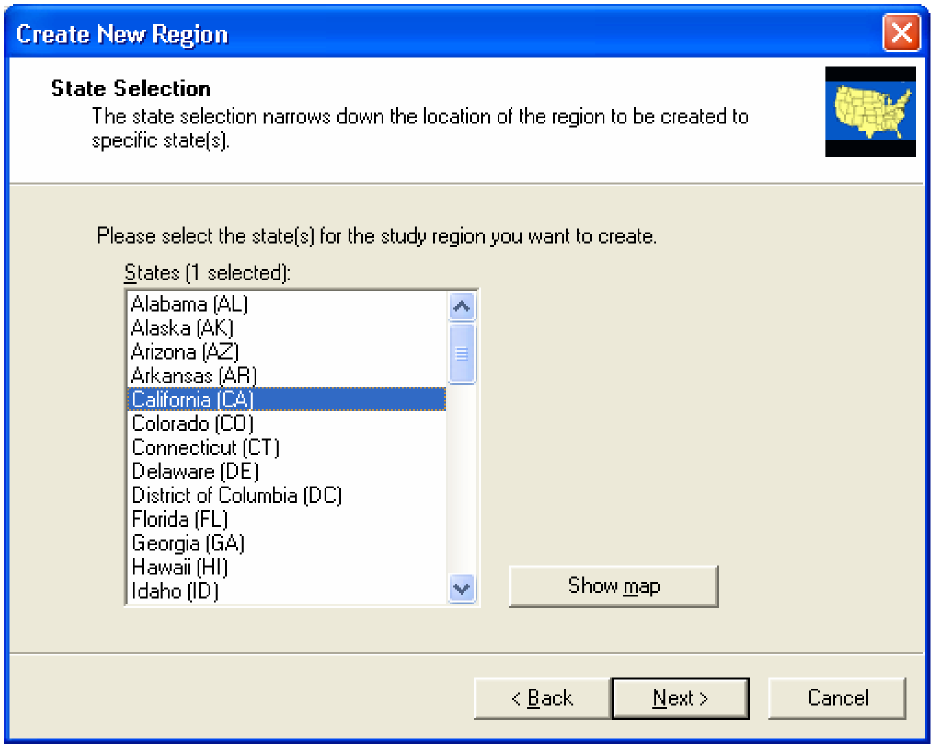
A.2.3 Select Earthquake Hazard



A.2.4 Select Aggregation at Tract Level

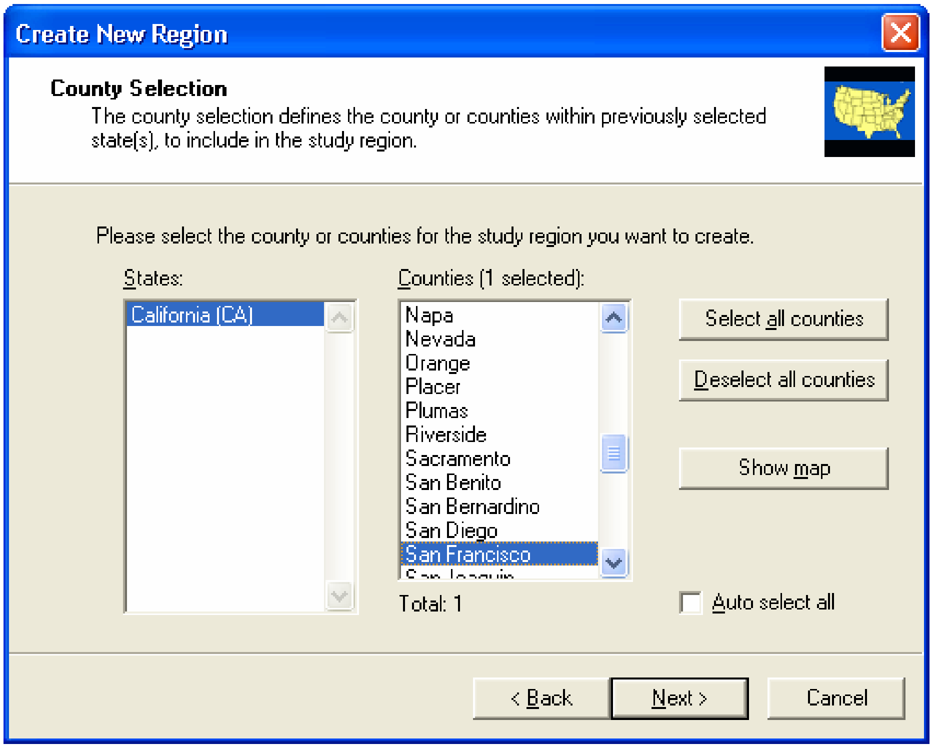


A.2.5 Select ‘California’



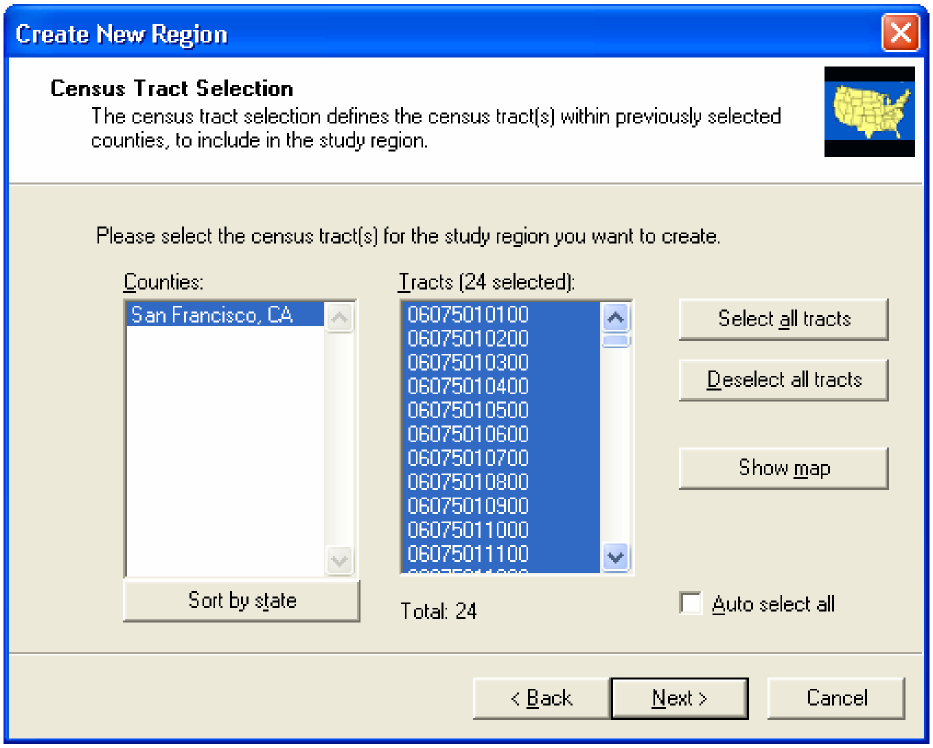
Note: This dialog needs the State Data DVD (DVD A1 in this case) or the Applications DVD (as it has the Verification Data), so make sure one of these is loaded in the DVD drive.

A.2.6 Select San Francisco County



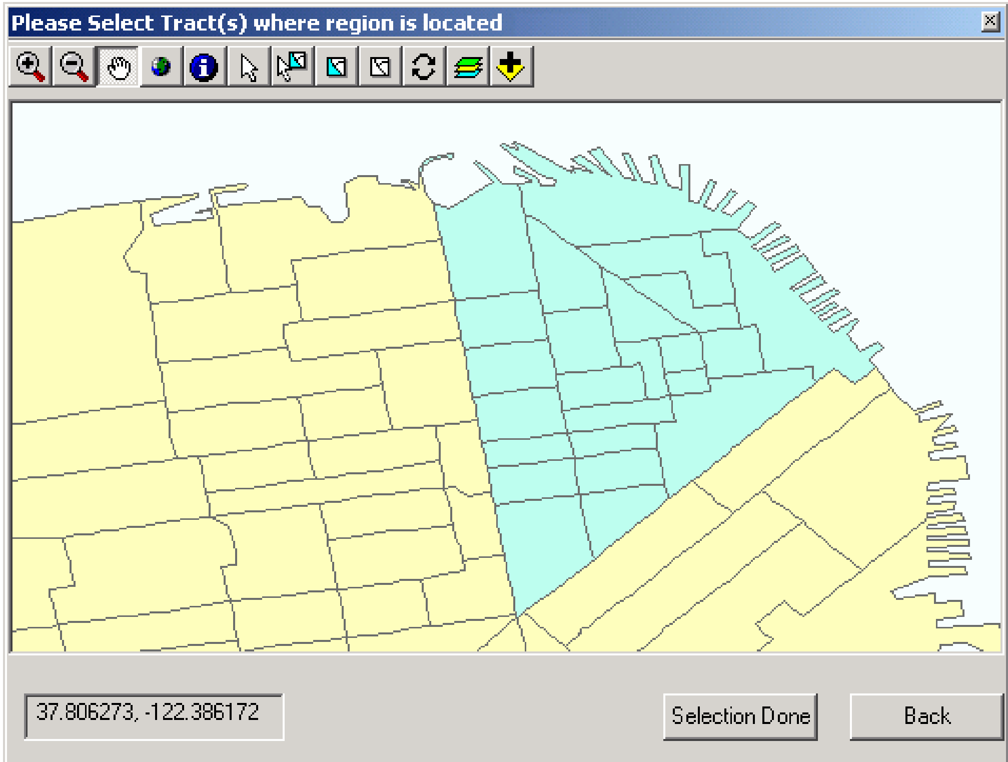
A.2.7 Select the Tracts

Select the first 24 tracts as shown below. While selecting with the mouse, press the “Shift” key or the “Ctrl” key to help with selection (Shift selects all entries from first selection to current selection, Ctrl toggles selects on/off for one entry)

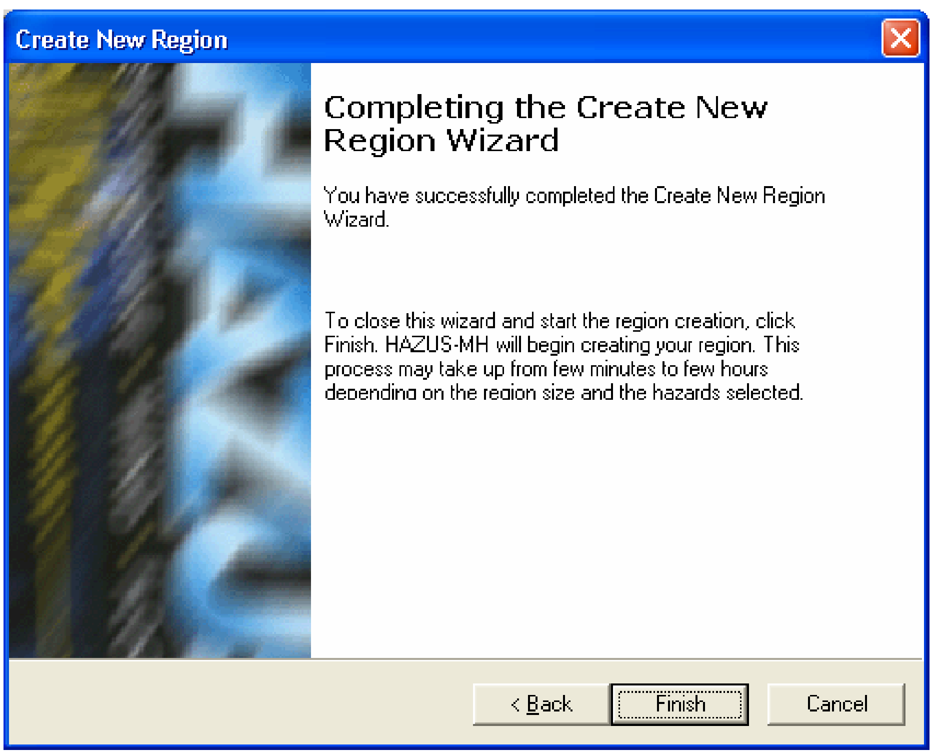


A.2.8 Confirm Selection From Map

Click 'Show map' and zoom in to confirm selection as shown below. Click 'Back' to return to main dialog.



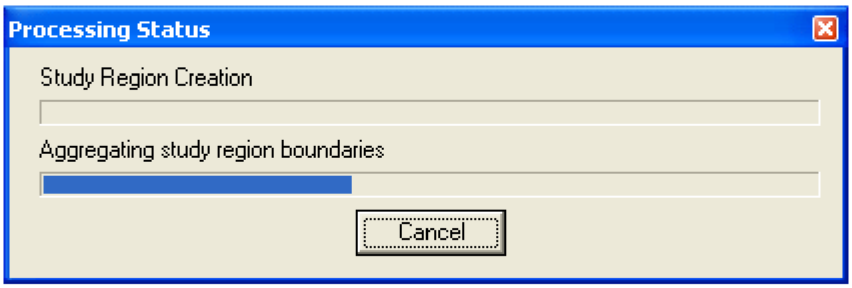
A.2.9 Finish the Wizard



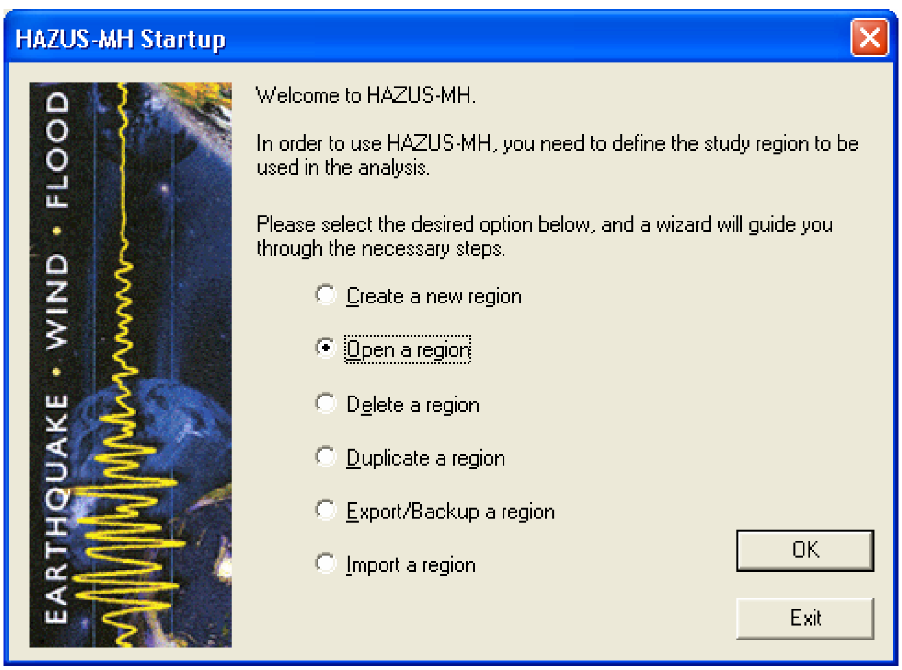
At this point, HAZUS-MH may ask for DVD A1, which is the DVD with the California data. If you have it, insert it or insert the “Application DVD”. If you already have one of these DVDs in the DVD Drive then HAZUS-MH will not ask for the DVD and will directly proceed to the next step.

A.2.10 Wait for Region to be created

A progress bar will display and the HAZUS-MH “shell” will create the study region. It will about 10 minutes to create the study region.

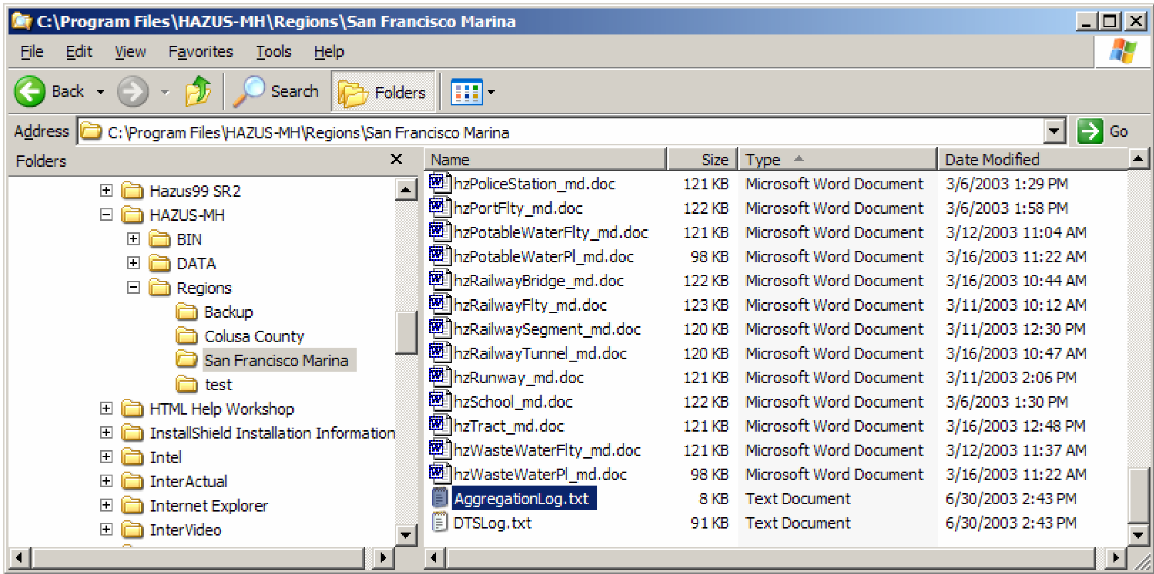


When the study region creation process is complete, you should see the following screen:



A folder with the study region name should be created underneath the folder where regions are kept (the default location is C:\Program Files\HAZUS-MH\ but in the example shown below the study regions are stored in C:\Program Files\HAZUS-MH\Regions). There should be many files in that folder, but the following 2 files are of particular interest: DTSLog.txt and

`AggregationLog.txt`: These files contain details of the steps executed in of the study region creation process. Should anything not work properly, these will be key files to examine.

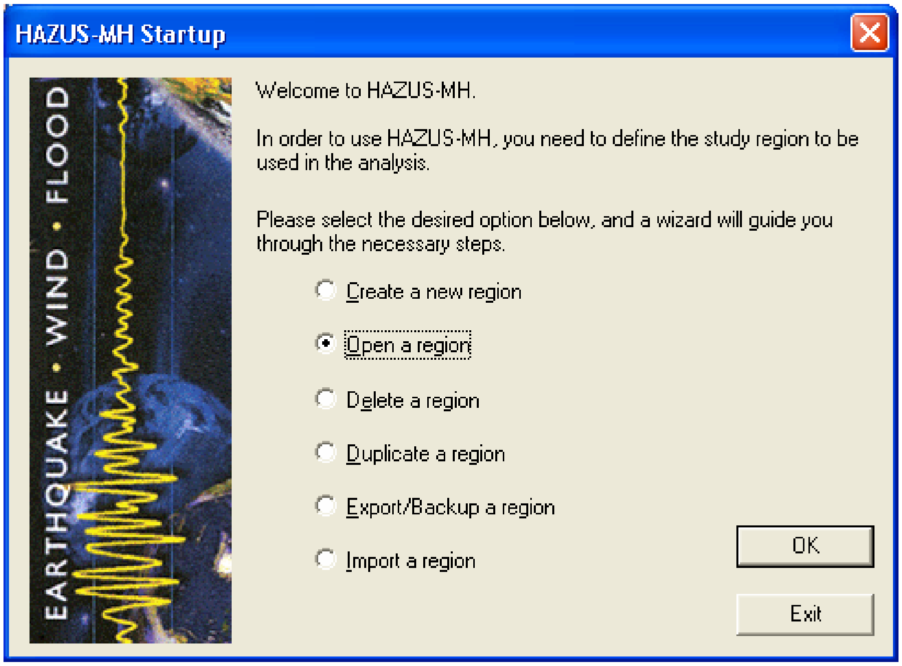


A.3 Study Region Open Verification Procedure

These steps will demonstrate that an earthquake study region can be opened.

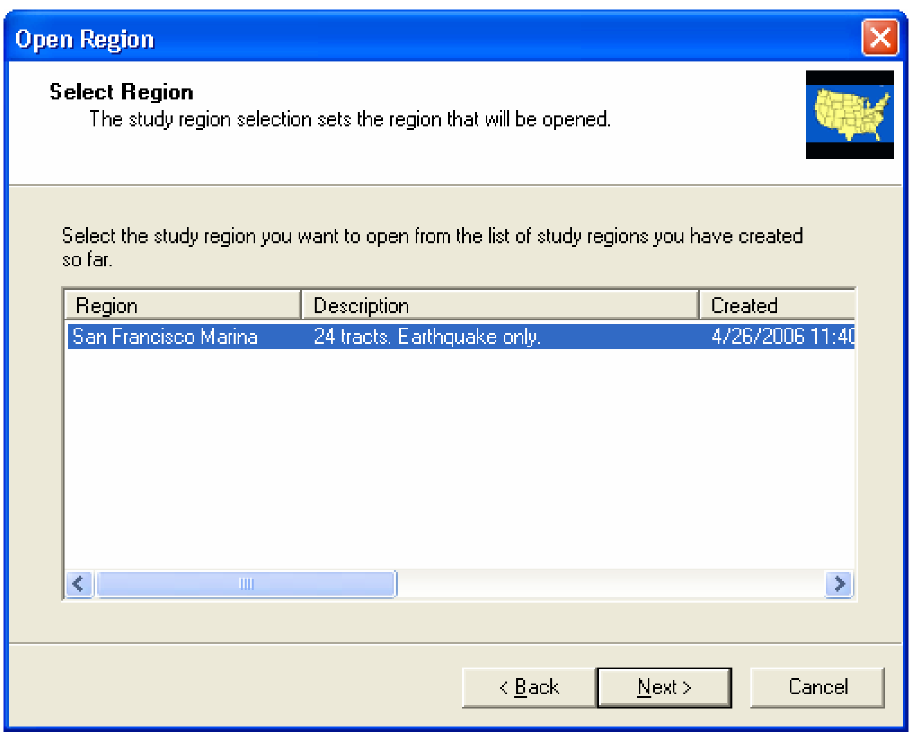
A.3.1 Open the New Region

When the creation process ended, the progress and creation dialogs should have gone away leaving the region wizard dialog on screen. Select “Open a region”.



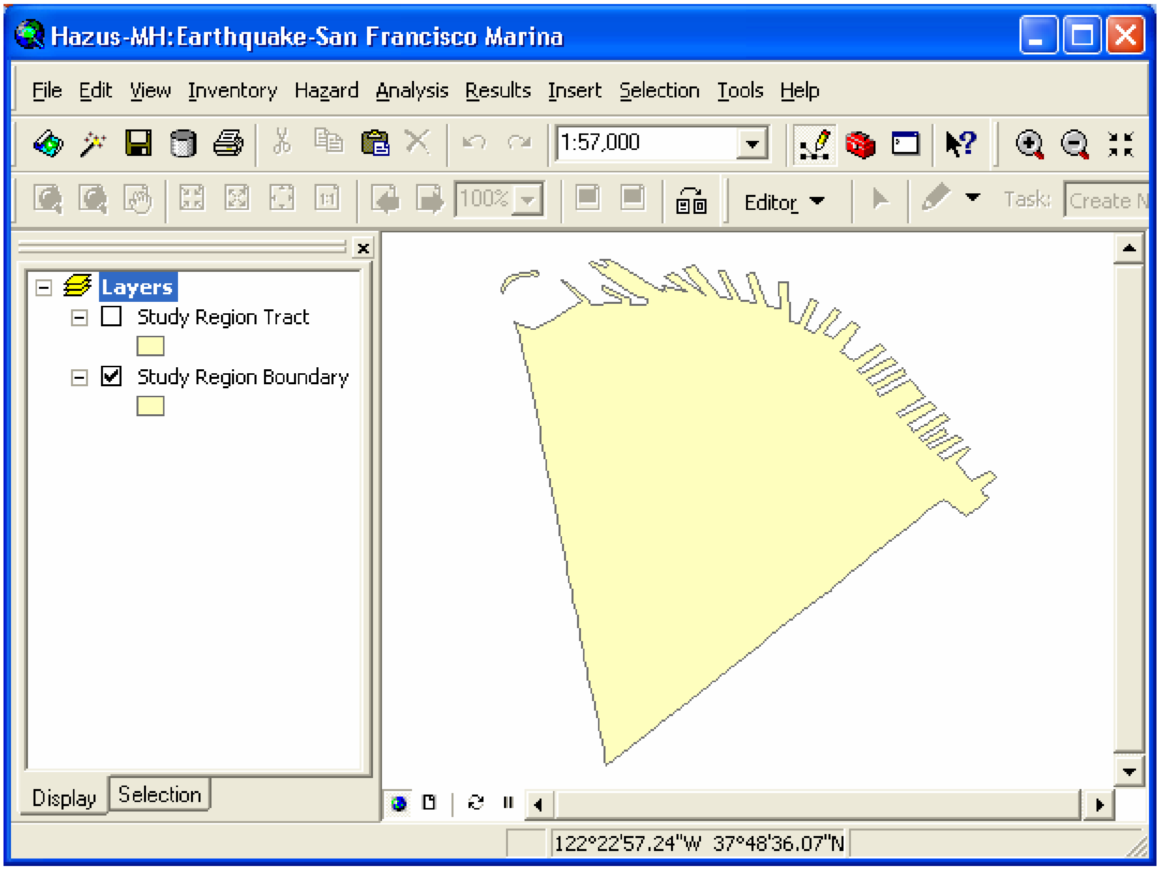
A.3.2 Select the New Region

The region you created will be the only one listed if this is truly the first region created.



A.3.3 Initial Display

Once the region opens it should look like following figure. The key elements to ensure are that the study region name is in the title bar, the Inventory, Hazard, Analysis, and Results menu items exist, and the two default layers are in the table of contents.

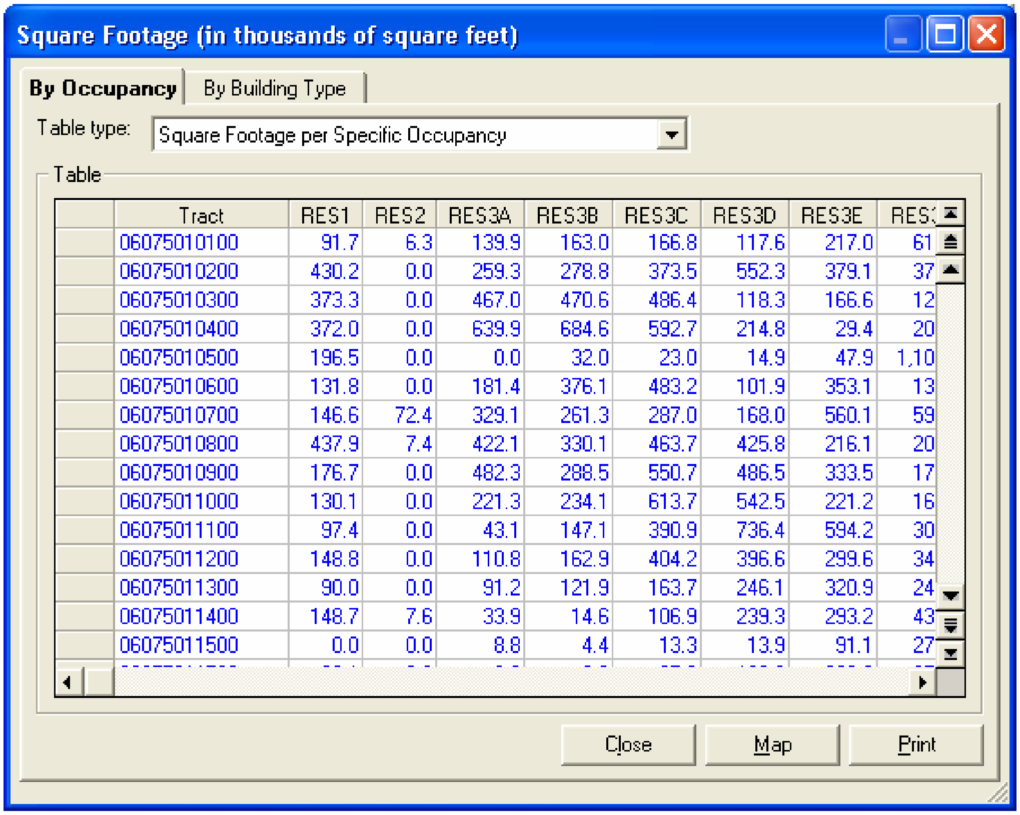


A.4 Inventory Verification

These steps will demonstrate that the Inventory menu items are functional and that inventory and certain occupancy mapping data were created.

A.4.1 General Build Stock Check

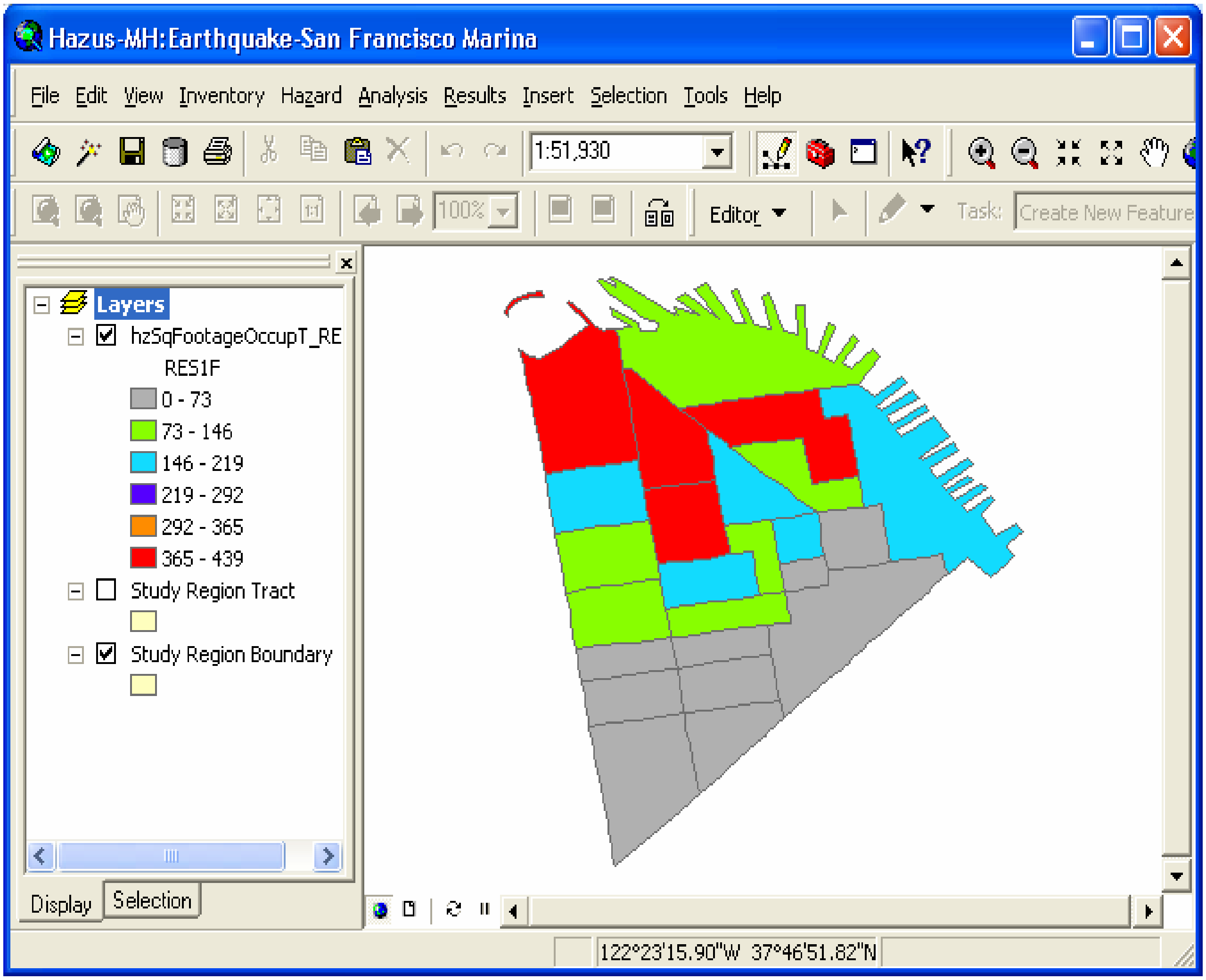
Use menu item Inventory | General Building Stock | Square Footage and ensure this displays. Close the dialog when finished.



	Tract	RES1	RES2	RES3A	RES3B	RES3C	RES3D	RES3E	RES
	06075010100	91.7	6.3	139.9	163.0	166.8	117.6	217.0	61
	06075010200	430.2	0.0	259.3	278.8	373.5	552.3	379.1	37
	06075010300	373.3	0.0	467.0	470.6	486.4	118.3	166.6	12
	06075010400	372.0	0.0	639.9	684.6	592.7	214.8	29.4	20
	06075010500	196.5	0.0	0.0	32.0	23.0	14.9	47.9	1,10
	06075010600	131.8	0.0	181.4	376.1	483.2	101.9	353.1	13
	06075010700	146.6	72.4	329.1	261.3	287.0	168.0	560.1	59
	06075010800	437.9	7.4	422.1	330.1	463.7	425.8	216.1	20
	06075010900	176.7	0.0	482.3	288.5	550.7	486.5	333.5	17
	06075011000	130.1	0.0	221.3	234.1	613.7	542.5	221.2	16
	06075011100	97.4	0.0	43.1	147.1	390.9	736.4	594.2	30
	06075011200	148.8	0.0	110.8	162.9	404.2	396.6	299.6	34
	06075011300	90.0	0.0	91.2	121.9	163.7	246.1	320.9	24
	06075011400	148.7	7.6	33.9	14.6	106.9	239.3	293.2	43
	06075011500	0.0	0.0	8.8	4.4	13.3	13.9	91.1	27

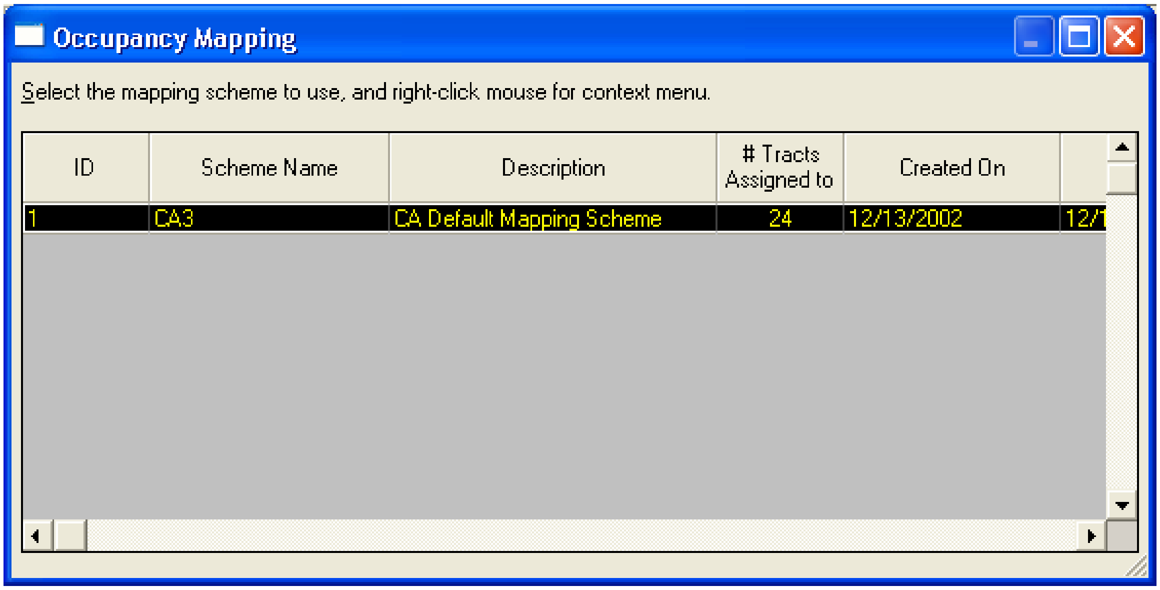
A.4.2 Shade by Res1

Click on the RES1 column header to select column RES1, and press the ‘Map’ button. A new shaded layer should be added to the map and show the distribution of RES1 occupancies. Click ‘Close’ to close the dialog when finished.

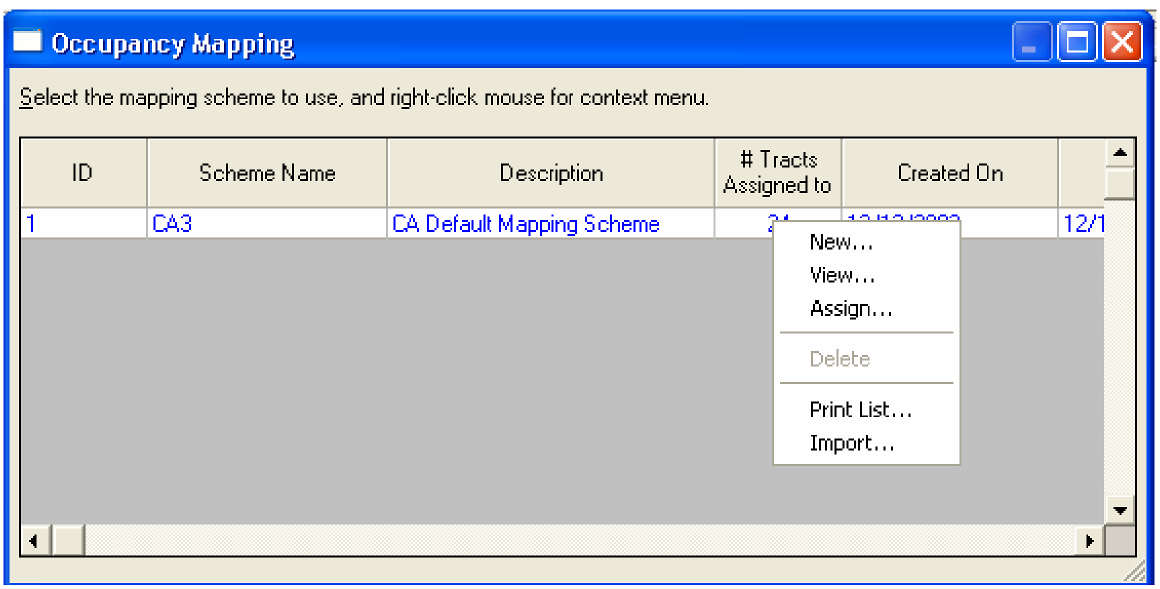


A.4.3 General Building Occupancy Mapping Check

Use menu item Inventory\General Building Stock | General Building Occupancy Mapping and ensure this displays.

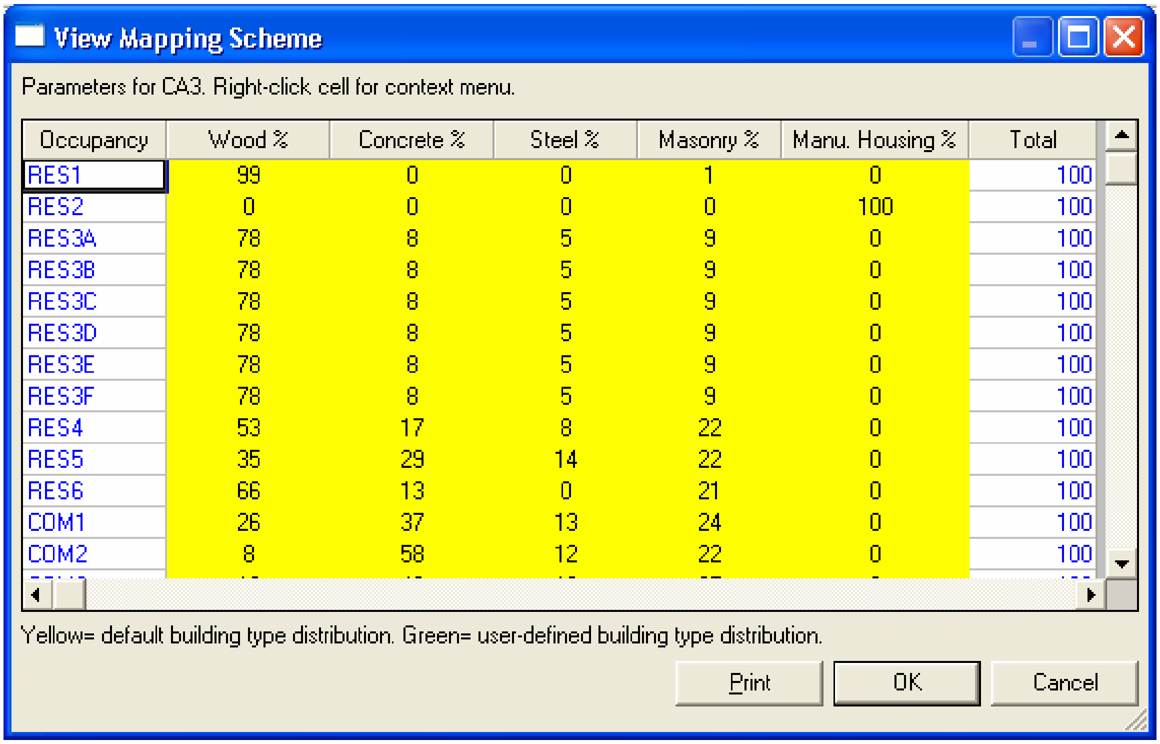


The list has one default mapping scheme called appropriately “CA Default Mapping Scheme”. To view the values associated with this default mapping scheme, right-click the row to get the context menu, and select “View…”.

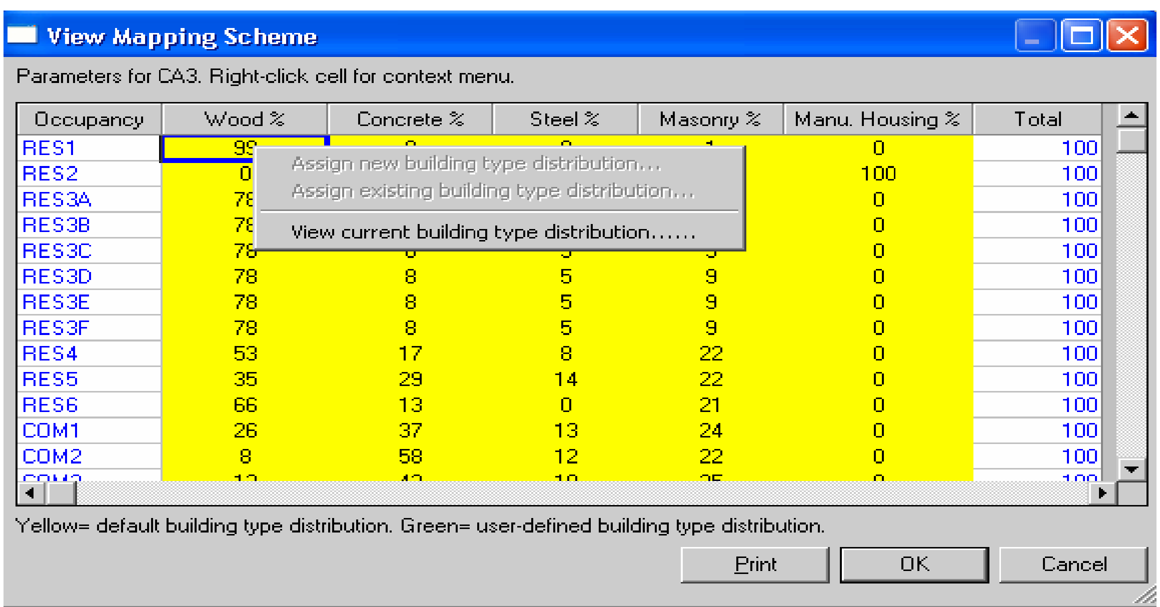


The values for the general mapping schemes are displayed. It shows for example that the distribution for RES1[1] buildings is 99% wood, and 1 % masonry.

[1] RES1 is the specific occupancy class for single family dwellings.

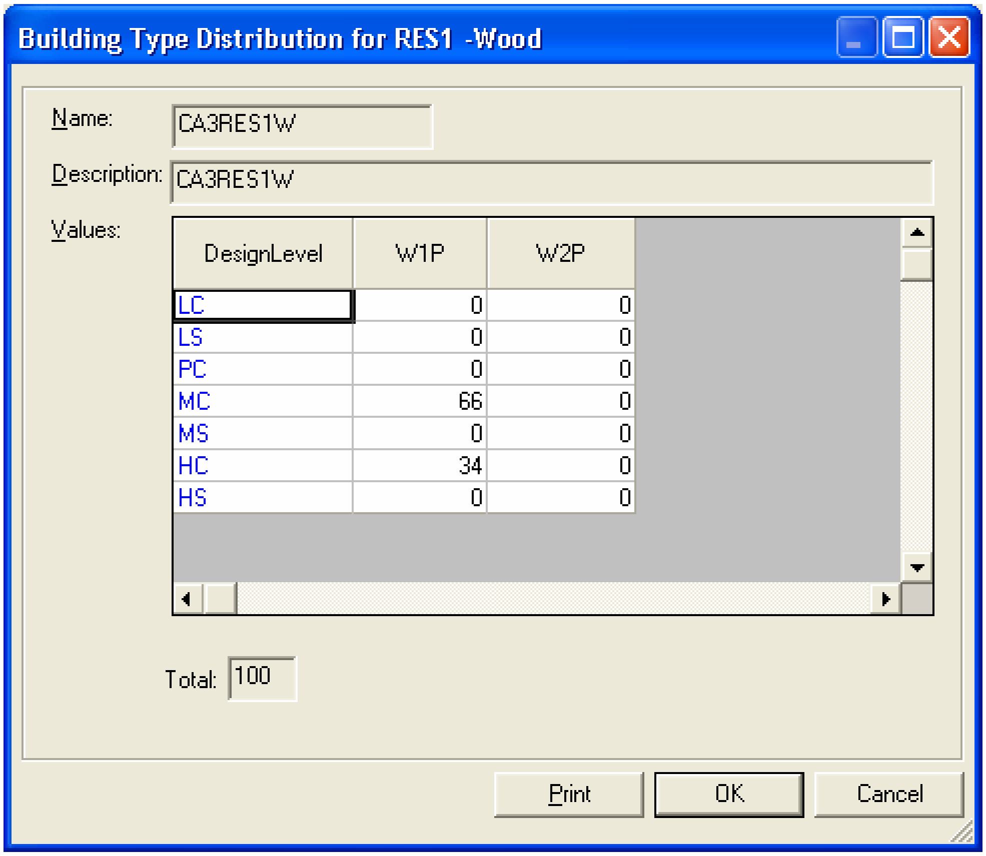


In the earthquake model, wood is further divided into 2 specific building types. The distribution from general building type (wood) into its specific building type is stored in *distribution matrices*. To view the distribution matrix, right-click the cell, and select "View current building type distribution…".



The following dialog shows that the default distribution for wood is as follows:

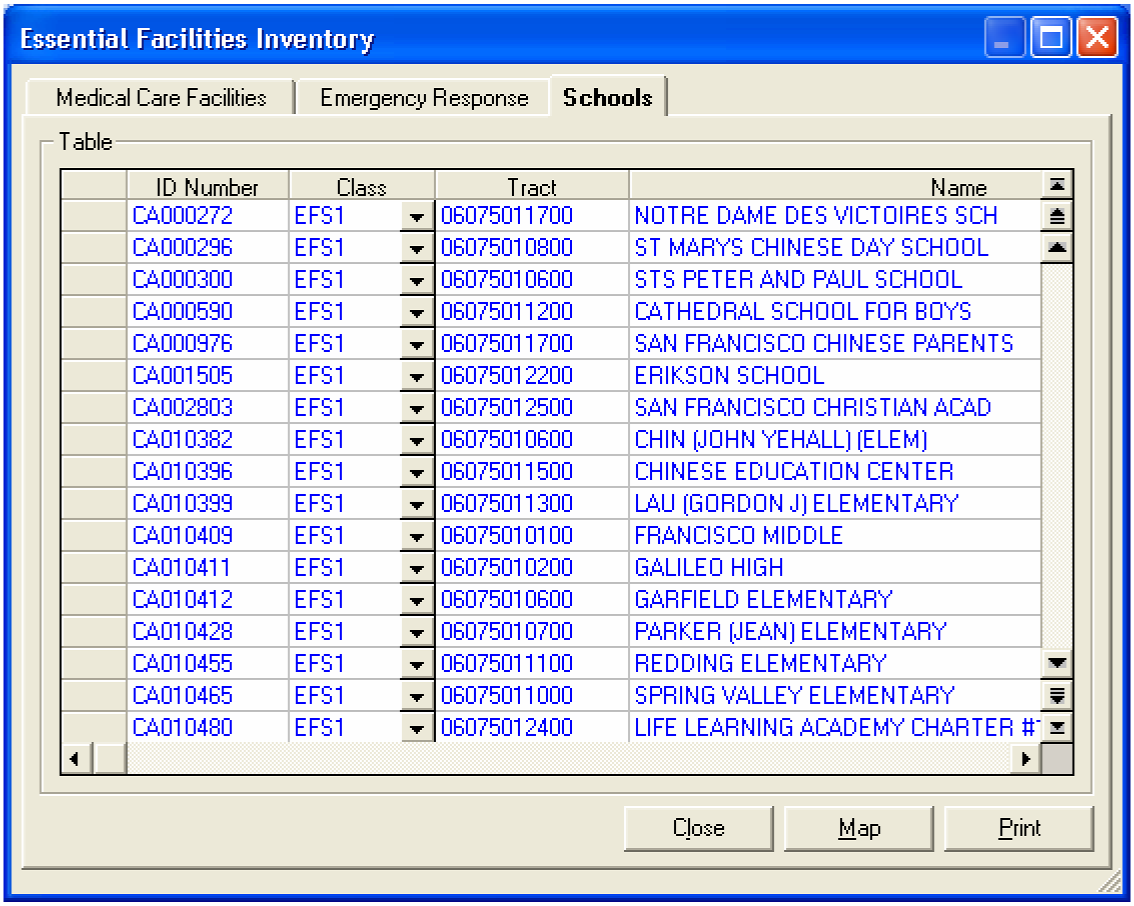
- 66% is W1 (wood light frame < 5,000 sq.ft.) with building quality up to Code and Medium earthquake design level.
- 34% is W1 with building quality up to Code and High earthquake design level.



Close the dialogs by clicking ‘Cancel’.

A.4.4 Essential Facilities Check

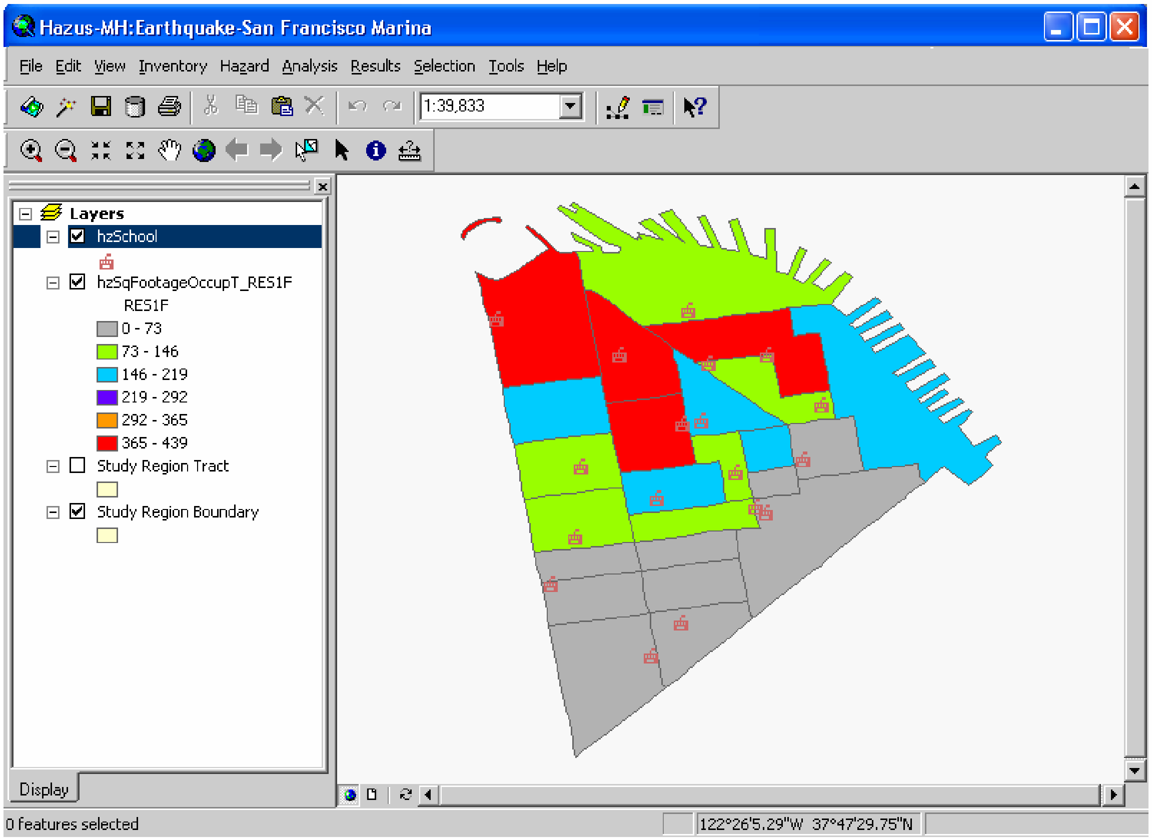
Select Inventory | Essential Facilities, then click on the Schools tab, and ensure the following dialog displays.



ID Number	Class	Tract	Name
CA000272	EFS1	06075011700	NOTRE DAME DES VICTOIRES SCH
CA000296	EFS1	06075010800	ST MARYS CHINESE DAY SCHOOL
CA000300	EFS1	06075010600	STS PETER AND PAUL SCHOOL
CA000590	EFS1	06075011200	CATHEDRAL SCHOOL FOR BOYS
CA000976	EFS1	06075011700	SAN FRANCISCO CHINESE PARENTS
CA001505	EFS1	06075012200	ERIKSON SCHOOL
CA002803	EFS1	06075012500	SAN FRANCISCO CHRISTIAN ACAD
CA010382	EFS1	06075010600	CHIN (JOHN YEHALL) (ELEM)
CA010396	EFS1	06075011500	CHINESE EDUCATION CENTER
CA010399	EFS1	06075011300	LAU (GORDON J) ELEMENTARY
CA010409	EFS1	06075010100	FRANCISCO MIDDLE
CA010411	EFS1	06075010200	GALILEO HIGH
CA010412	EFS1	06075010600	GARFIELD ELEMENTARY
CA010428	EFS1	06075010700	PARKER (JEAN) ELEMENTARY
CA010455	EFS1	06075011100	REDDING ELEMENTARY
CA010465	EFS1	06075011000	SPRING VALLEY ELEMENTARY
CA010480	EFS1	06075012400	LIFE LEARNING ACADEMY CHARTER #

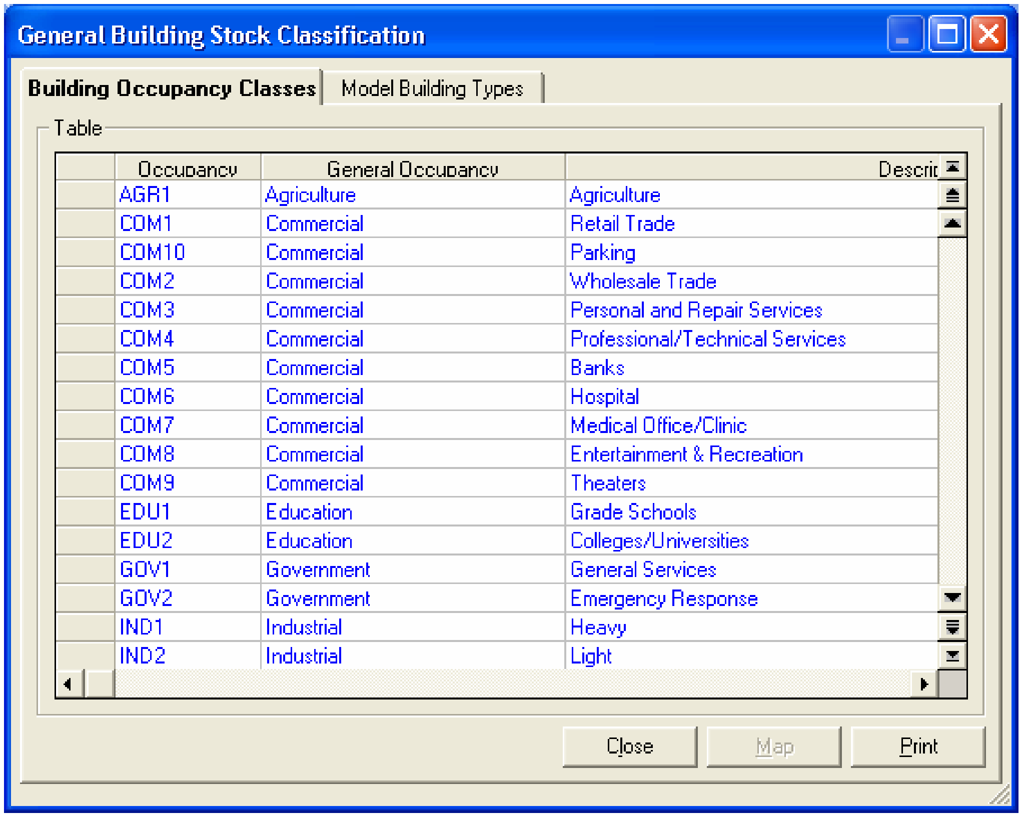
A.4.5 Plot the Schools

Press Map. A new map layer should get added to the TOC (Table of Contents) that shows the location of schools in our study region.



A.4.6 Classification Check

Use menu item Inventory | View Classifications | General Building Stock to ensure the following dialog appears. Close the dialog when finished. This completes the Inventory.


General Building Stock Classification
Building Occupancy Classes
Model Building Types
Table
Occupancy
General Occupancy
Descrip
AGR1 Agriculture Agriculture
COM1 Commercial Retail Trade
COM10 Commercial Parking
COM2 Commercial Wholesale Trade
COM3 Commercial Personal and Repair Services
COM4 Commercial Professional/Technical Services
COM5 Commercial Banks
COM6 Commercial Hospital
COM7 Commercial Medical Office/Clinic
COM8 Commercial Entertainment & Recreation
COM9 Commercial Theaters
EDU1 Education Grade Schools
EDU2 Education Colleges/Universities
GOV1 Government General Services
GOV2 Government Emergency Response
IND1 Industrial Heavy
IND2 Industrial Light
Close
Map
Print

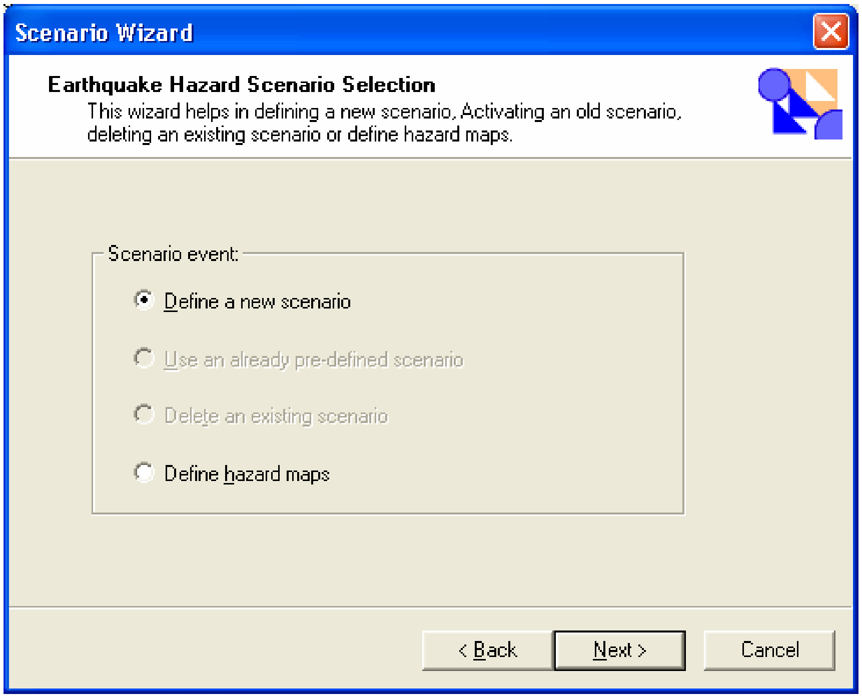
A.5 Hazard Verification – Deterministic Hazard

These steps will demonstrate that the arbitrary earthquake event is functioning properly.

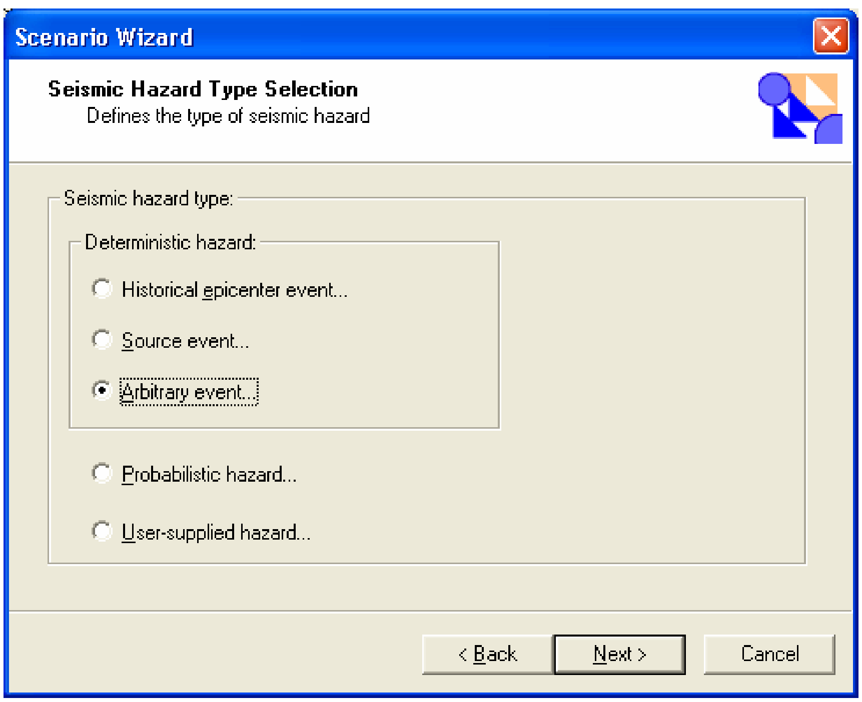
A.5.1 Set the Active Scenario to "Arbitrary"

Use the Hazard | Scenario menu to start the scenario wizard:

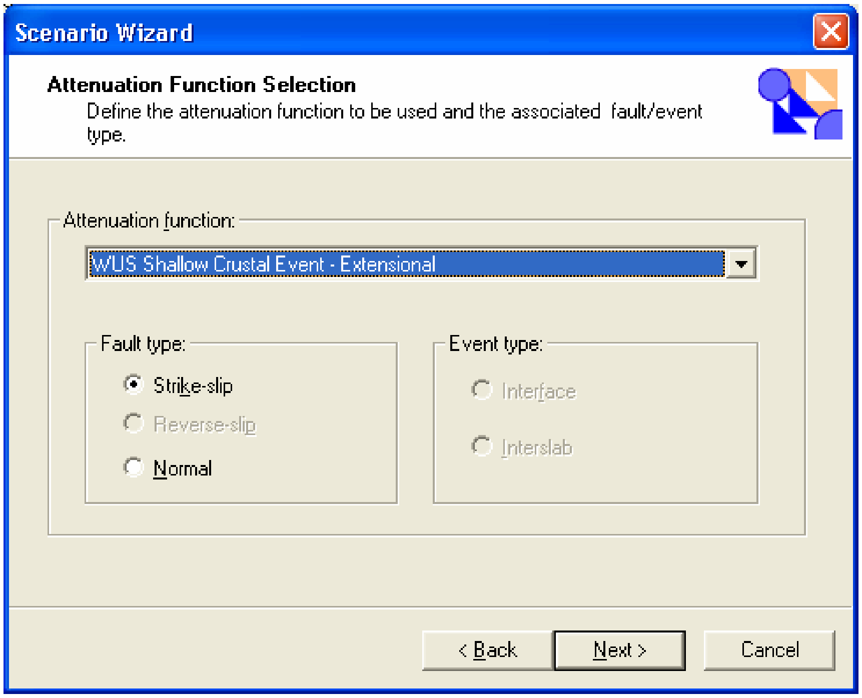
Click the Next button and choose to "Define a new scenario".



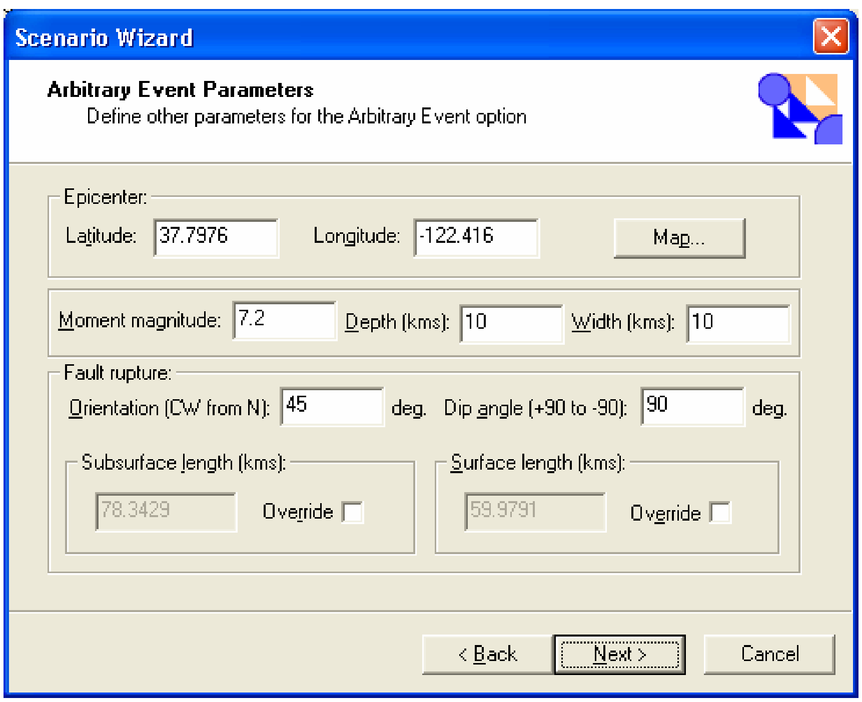
Select the "Arbitrary event" option, and click the Next button.



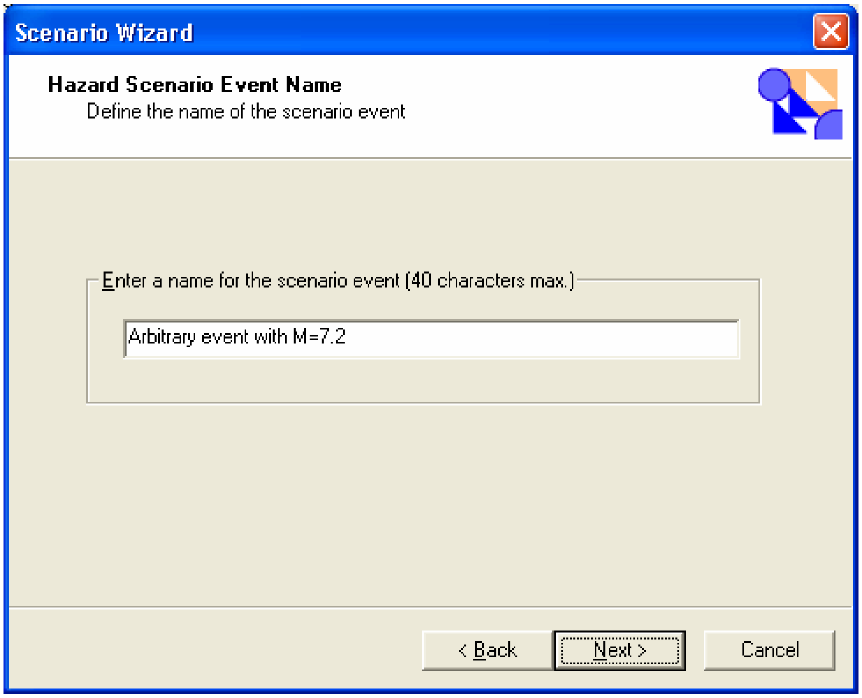
Select to use the "WUS Shallow Crustal event - Extensional" attenuation function.



Define the parameters of the arbitrary event exactly as shows in the following dialog.



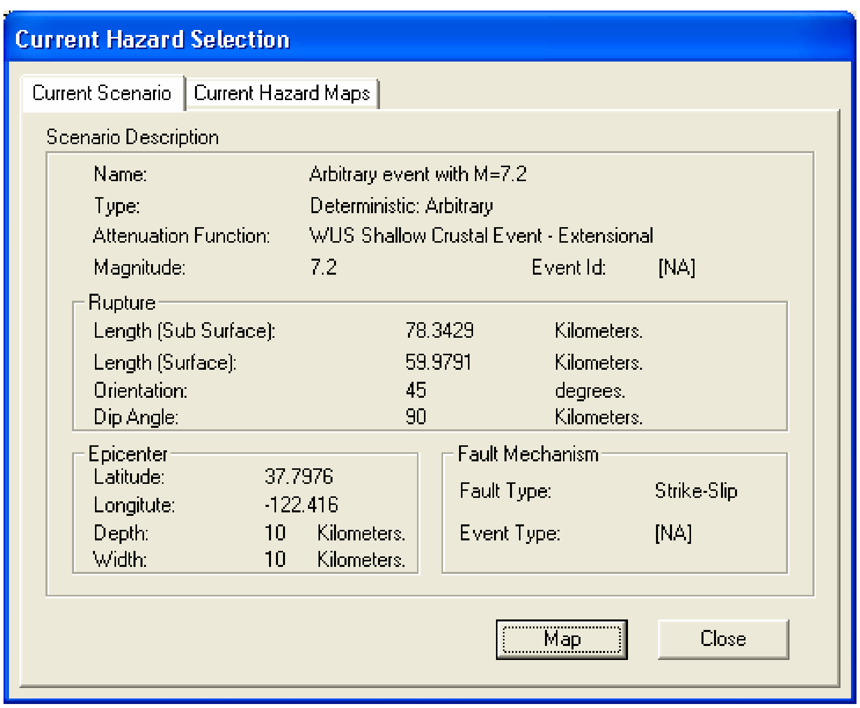
Name the event as follows and click the Next button. Click “Finish” at the last dialog to exit the wizard.



Click ‘Next’ and ‘Finish’ to create the scenario.

A.5.2 Show the Current Scenario

Use the Hazard | Current Scenario menu to review the current scenario.



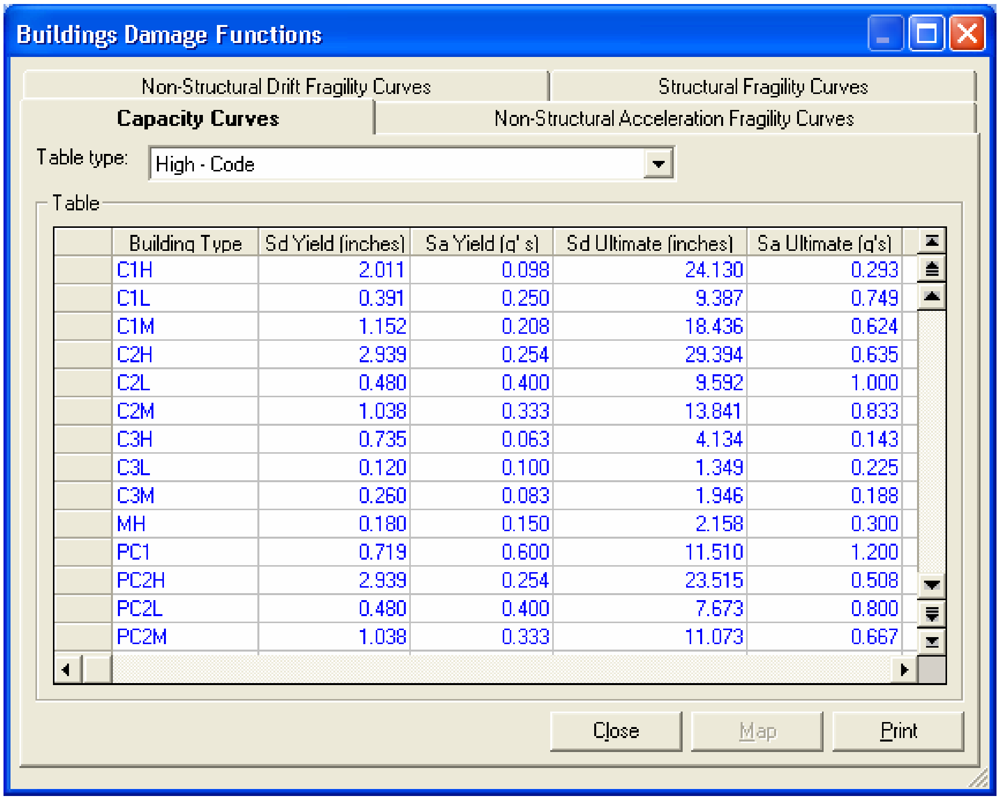
Click the Close button. This completes the Scenario menu.

A.6 Analysis Parameters Verification

These steps will demonstrate that the Analysis Parameters are functioning properly.

A.6.1 View Damage Functions

Click on the Analysis | Damage Functions | Buildings. Scroll to the right and resize some columns to get the screen below.

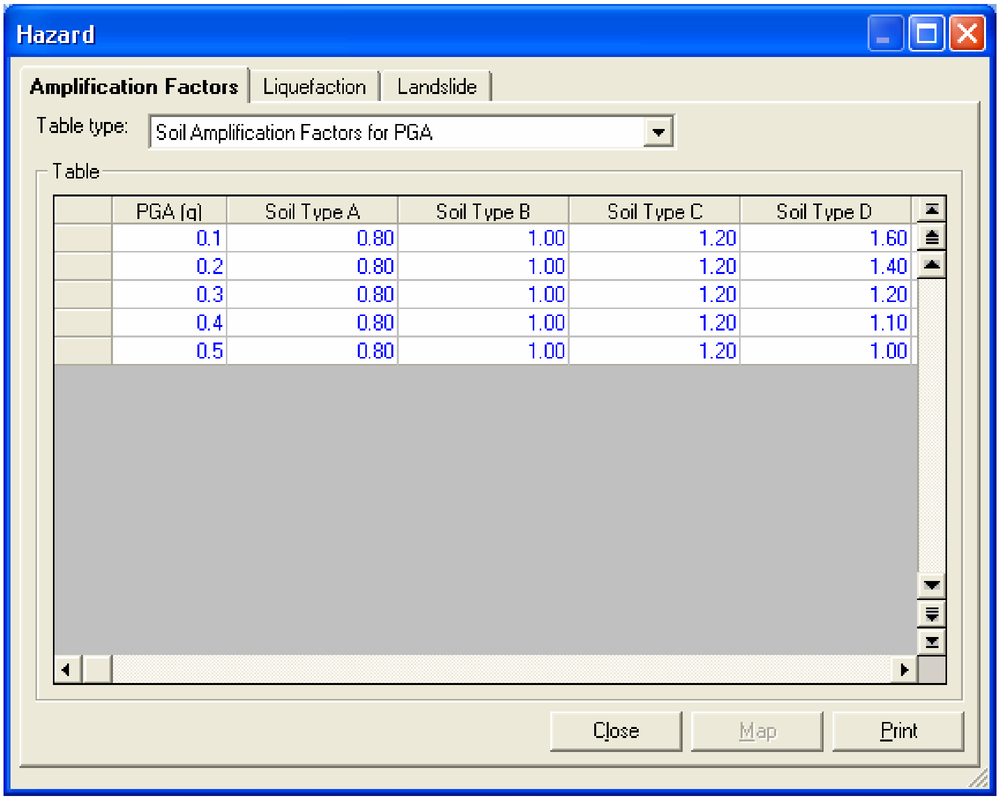


Building Type	Sd Yield (inches)	Sa Yield (g' s)	Sd Ultimate (inches)	Sa Ultimate (g's)
C1H	2.011	0.098	24.130	0.293
C1L	0.391	0.250	9.387	0.749
C1M	1.152	0.208	18.436	0.624
C2H	2.939	0.254	29.394	0.635
C2L	0.480	0.400	9.592	1.000
C2M	1.038	0.333	13.841	0.833
C3H	0.735	0.063	4.134	0.143
C3L	0.120	0.100	1.349	0.225
C3M	0.260	0.083	1.946	0.188
MH	0.180	0.150	2.158	0.300
PC1	0.719	0.600	11.510	1.200
PC2H	2.939	0.254	23.515	0.508
PC2L	0.480	0.400	7.673	0.800
PC2M	1.038	0.333	11.073	0.667

Close the window.

A.6.2 View Hazard Parameters

Click on Analysis | Parameters | Hazard. The following dialog should appear:



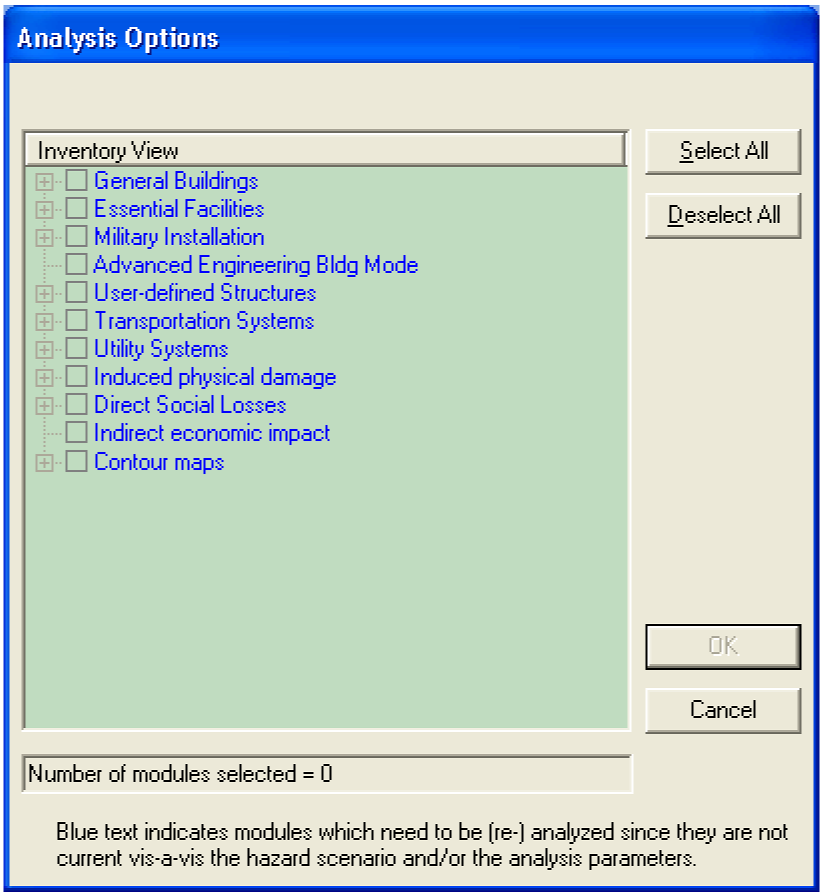
Close the dialog when done.

A.7 Analysis Run Verification

These steps will demonstrate that the Analysis Run Dialog is functioning properly.

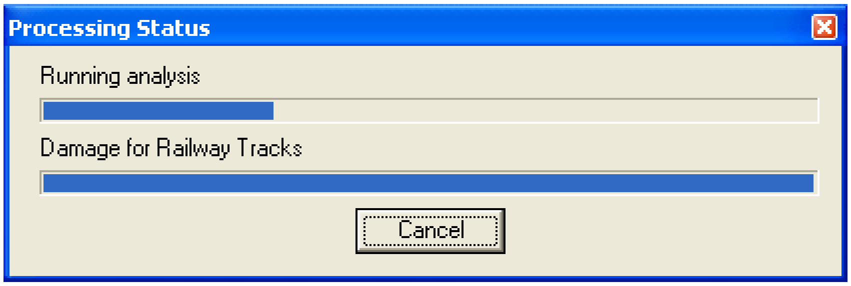
A.7.1 Open the Dialog

Click on the Analysis | Run menu option. This will bring up the analysis options dialog:



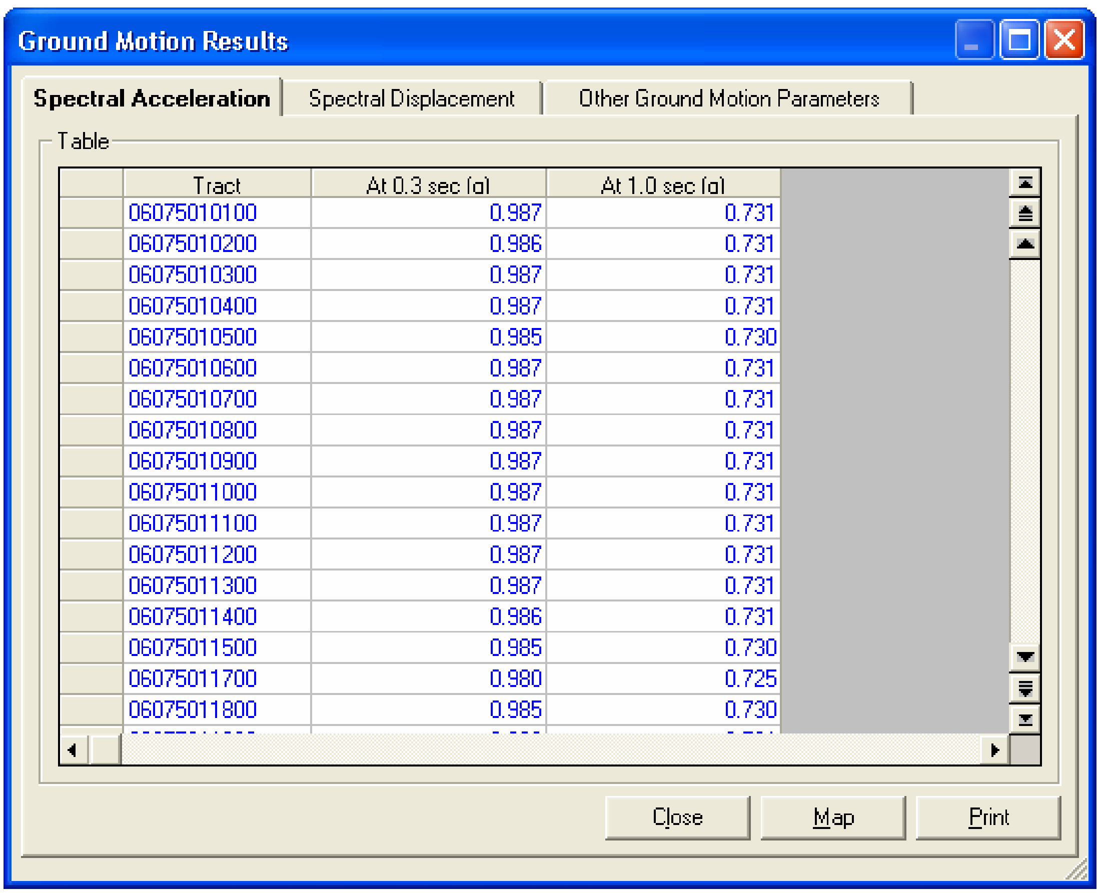
A.7.2 Start the Analysis

Click the "Select All" button and then "Run Analysis" to start the analysis. Answer 'Yes' to the following dialog. Click 'OK' and click 'Yes' to start the analysis. The "Processing Status" dialog is displayed showing the progress of the analysis. Once the analysis is completed, the dialog will close automatically (this scenario analysis will take about 3-5minutes on our typical machine).

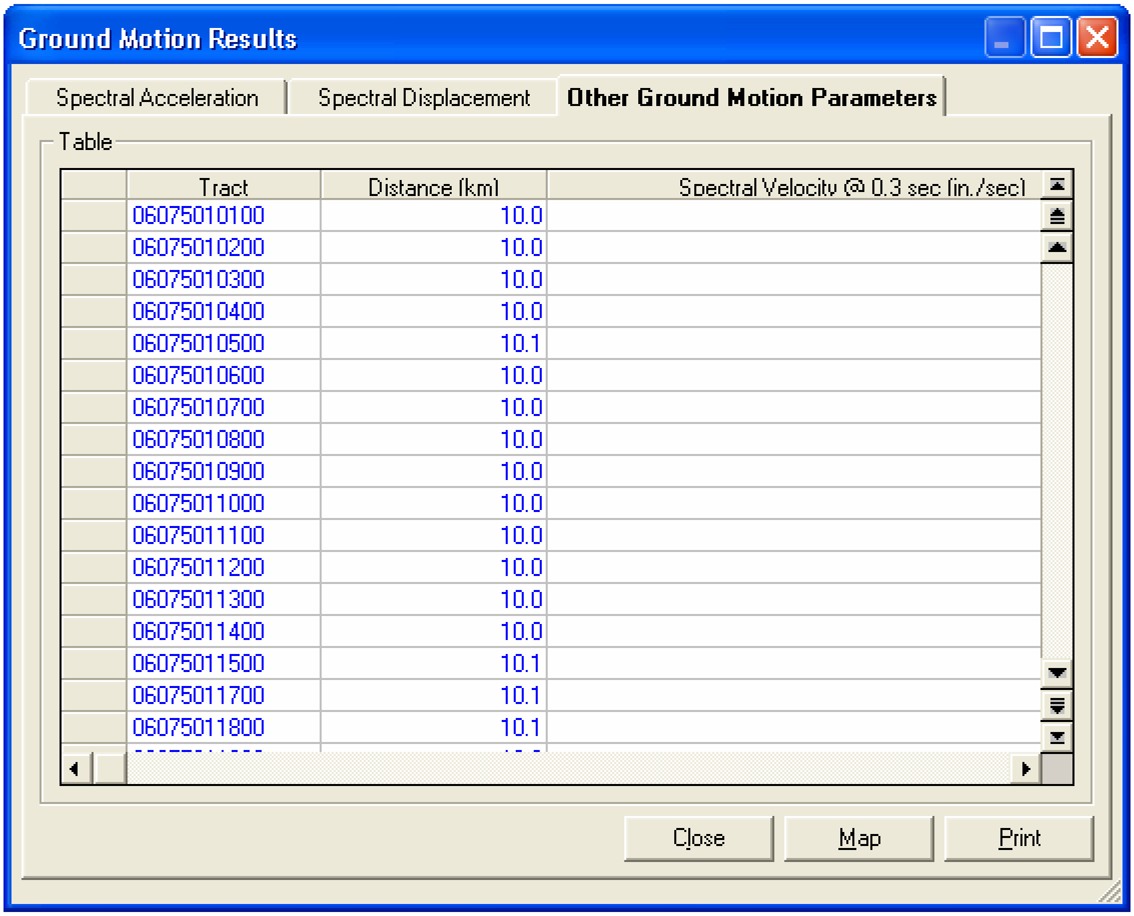


A.7.3 Viewing Ground Motion Results

Click on the Results | Ground Motion or Ground Failure | Ground Motion (By Census tract). This action will open the following dialog:



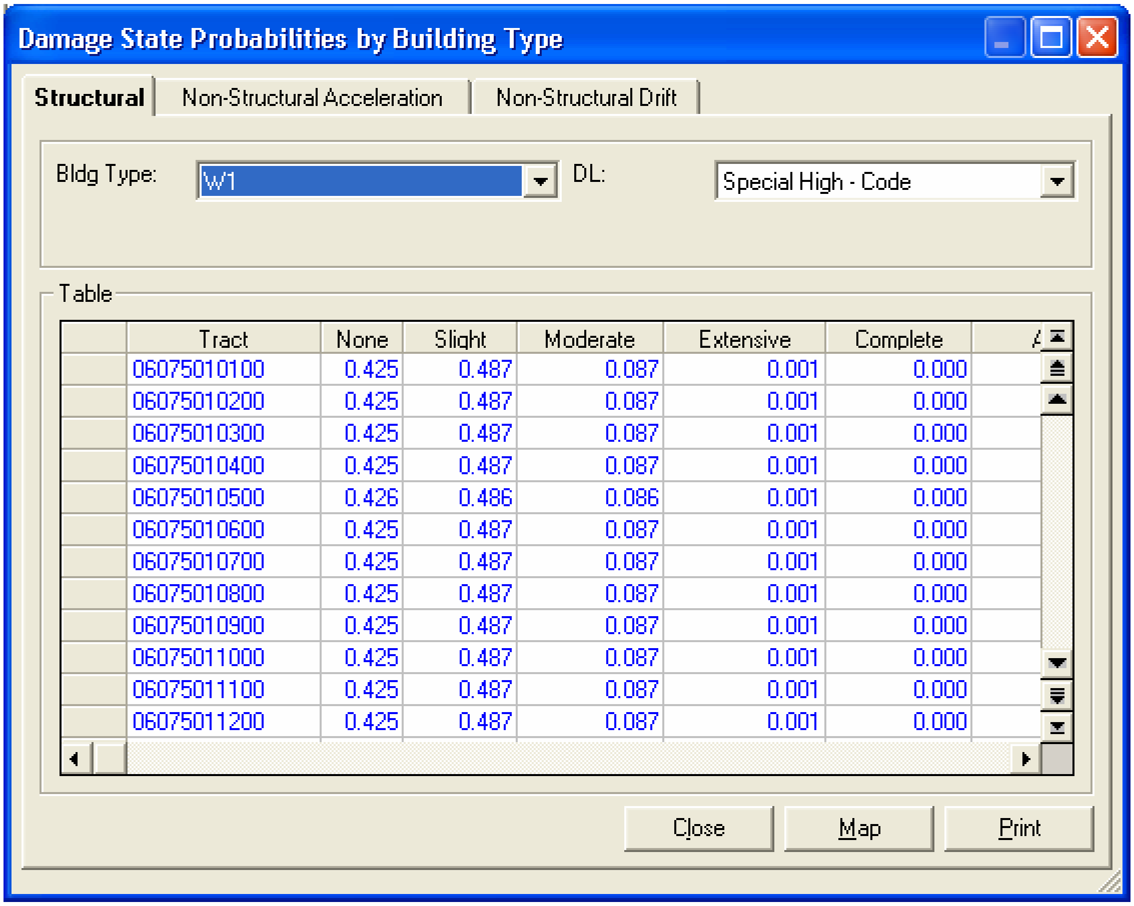
Because of the very small size of the region, the acceleration values are very close for the different tracts. Click the "Other Ground Motion Parameters" tab to get the following dialog.



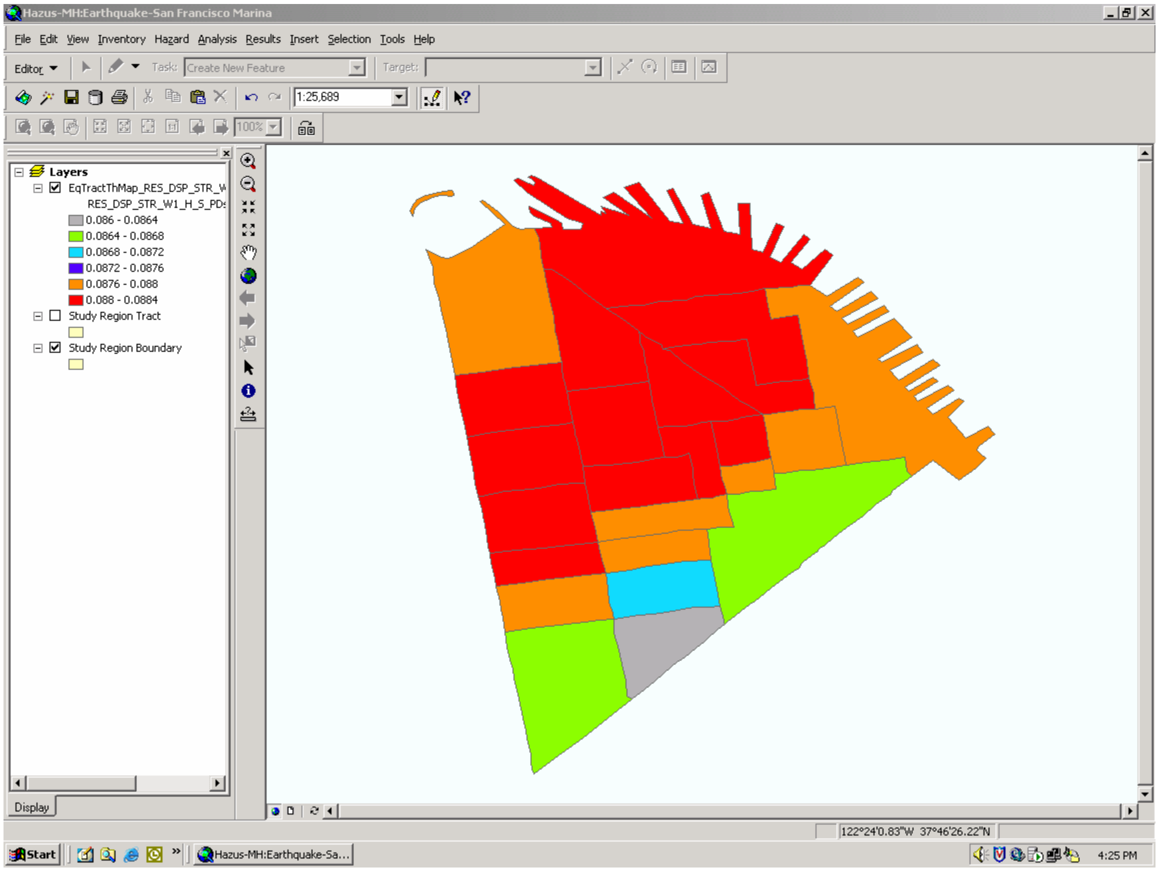
Distances to the earthquake epicenter range from 30 to 30.2 kilometers.

A.7.4 Viewing Building Damage Results

Click on the Results | General Building Stock | By Building Type. This action will open the following dialog:



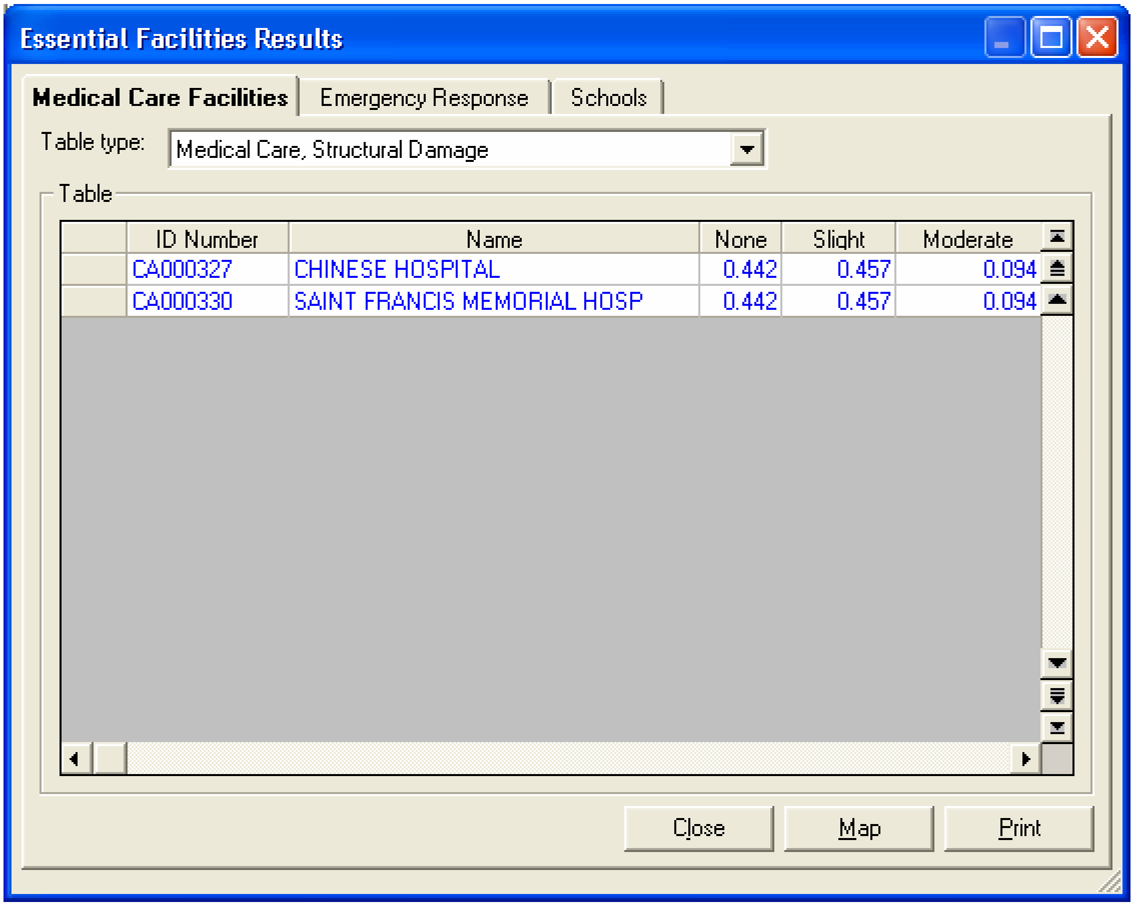
Select the “At Least Moderate” column and click on the map button. The following map should appear.



You can examine other results for any building type and/or design level/building quality combination by simply selecting the option from the two relevant combo-boxes.

A.7.5 Essential Facility Damage

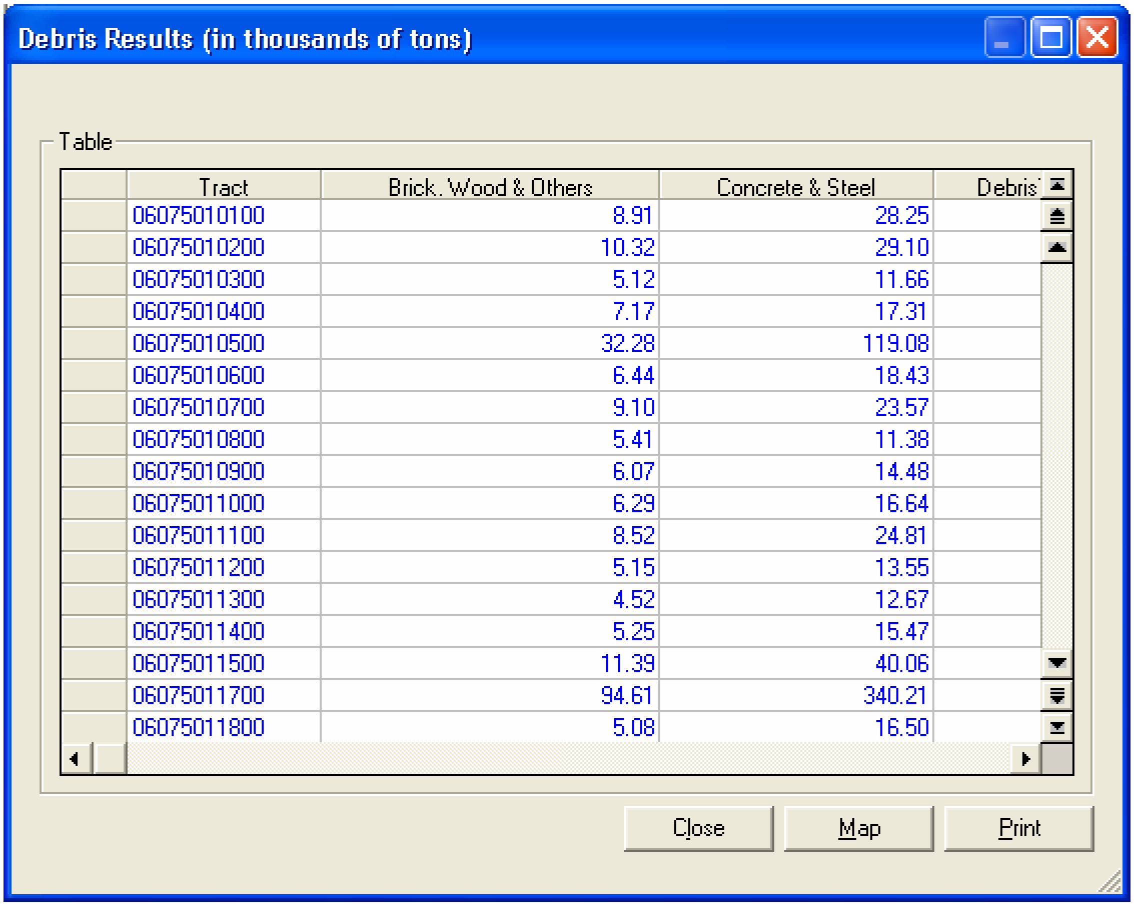
Click on the Results | Essential Facilities menu option. This action will open the following dialog:



You can view the results for the other essential facilities (emergency response and schools) by clicking the relevant tab.

A.7.6 Debris

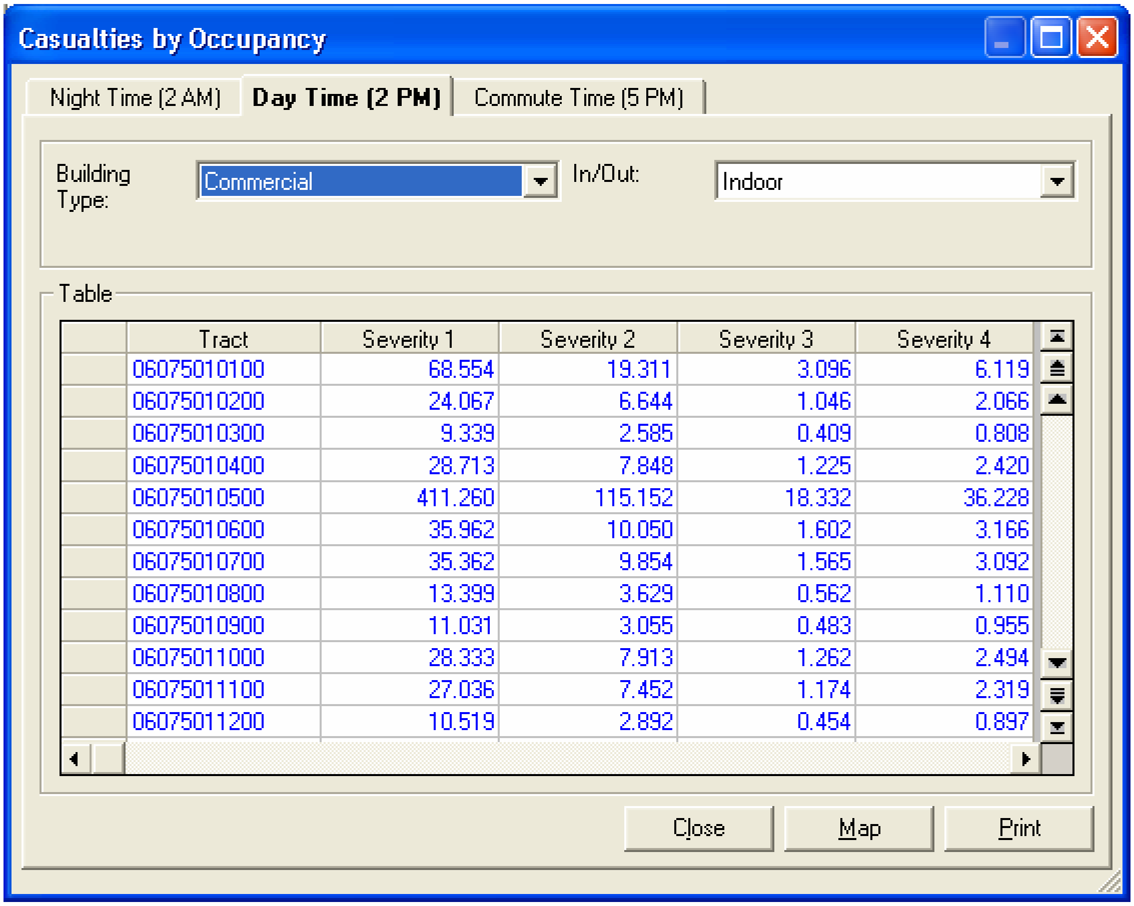
Click on the Results | Debris menu option. This action will open the following dialog:



Tract	Brick, Wood & Others	Concrete & Steel	Debris
06075010100	8.91	28.25	
06075010200	10.32	29.10	
06075010300	5.12	11.66	
06075010400	7.17	17.31	
06075010500	32.28	119.08	
06075010600	6.44	18.43	
06075010700	9.10	23.57	
06075010800	5.41	11.38	
06075010900	6.07	14.48	
06075011000	6.29	16.64	
06075011100	8.52	24.81	
06075011200	5.15	13.55	
06075011300	4.52	12.67	
06075011400	5.25	15.47	
06075011500	11.39	40.06	
06075011700	94.61	340.21	
06075011800	5.08	16.50	

A.7.7 Casualties

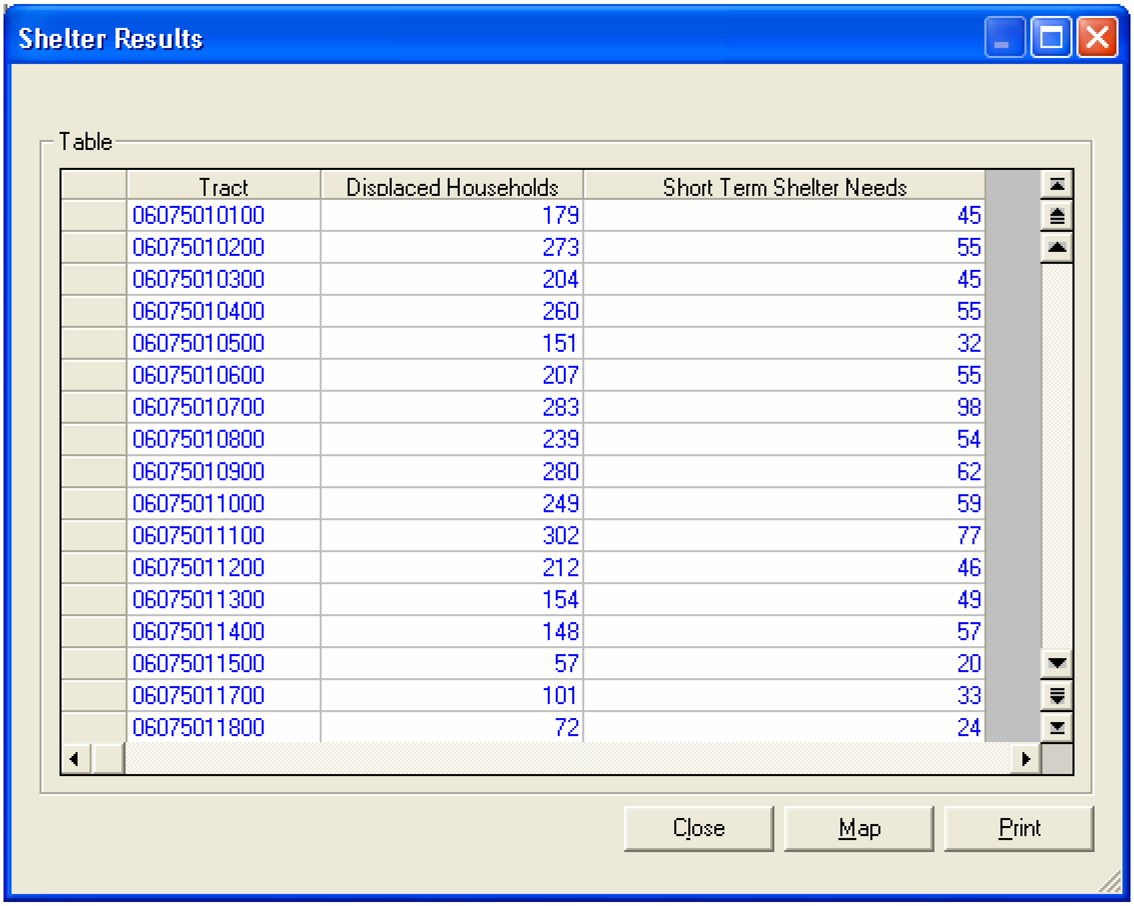
Click on Results | Casualties | By Occupancy. Select to view the indoor commercial casualties at 2PM (the time where most people will be in the offices). The following dialog appears.



Tract	Severity 1	Severity 2	Severity 3	Severity 4
06075010100	68.554	19.311	3.096	6.119
06075010200	24.067	6.644	1.046	2.066
06075010300	9.339	2.585	0.409	0.808
06075010400	28.713	7.848	1.225	2.420
06075010500	411.260	115.152	18.332	36.228
06075010600	35.962	10.050	1.602	3.166
06075010700	35.362	9.854	1.565	3.092
06075010800	13.399	3.629	0.562	1.110
06075010900	11.031	3.055	0.483	0.955
06075011000	28.333	7.913	1.262	2.494
06075011100	27.036	7.452	1.174	2.319
06075011200	10.519	2.892	0.454	0.897

A.7.8 Shelter Requirements

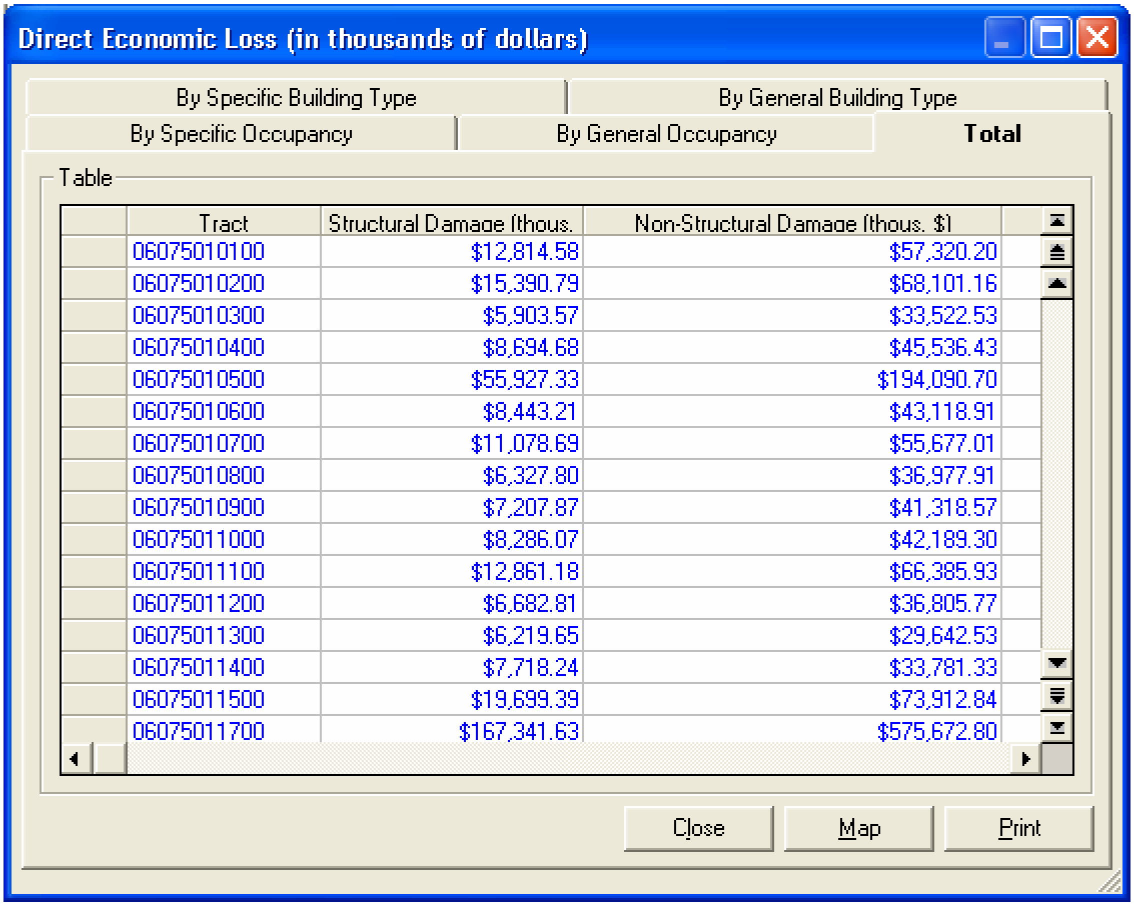
Click on the Results | Shelter menu option. This action will open the following dialog:



Tract	Displaced Households	Short Term Shelter Needs
06075010100	179	45
06075010200	273	55
06075010300	204	45
06075010400	260	55
06075010500	151	32
06075010600	207	55
06075010700	283	98
06075010800	239	54
06075010900	280	62
06075011000	249	59
06075011100	302	77
06075011200	212	46
06075011300	154	49
06075011400	148	57
06075011500	57	20
06075011700	101	33
06075011800	72	24

A.7.9 Direct Economic Losses

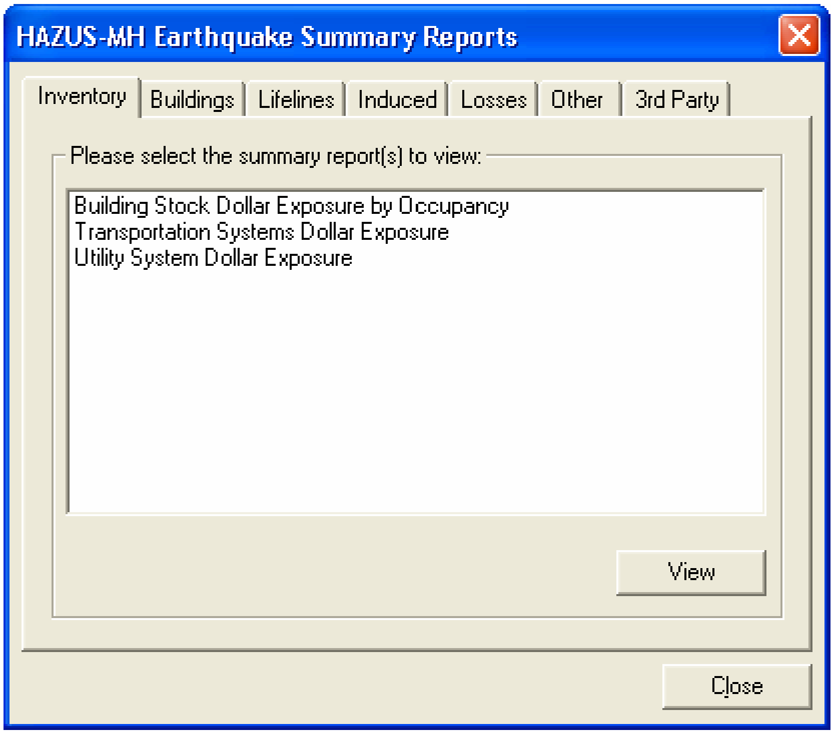
Click on the Results | Building Economic Loss. Select the 'Total' tab and resize the columns and the dialog itself to show 3 columns as in the following dialog.



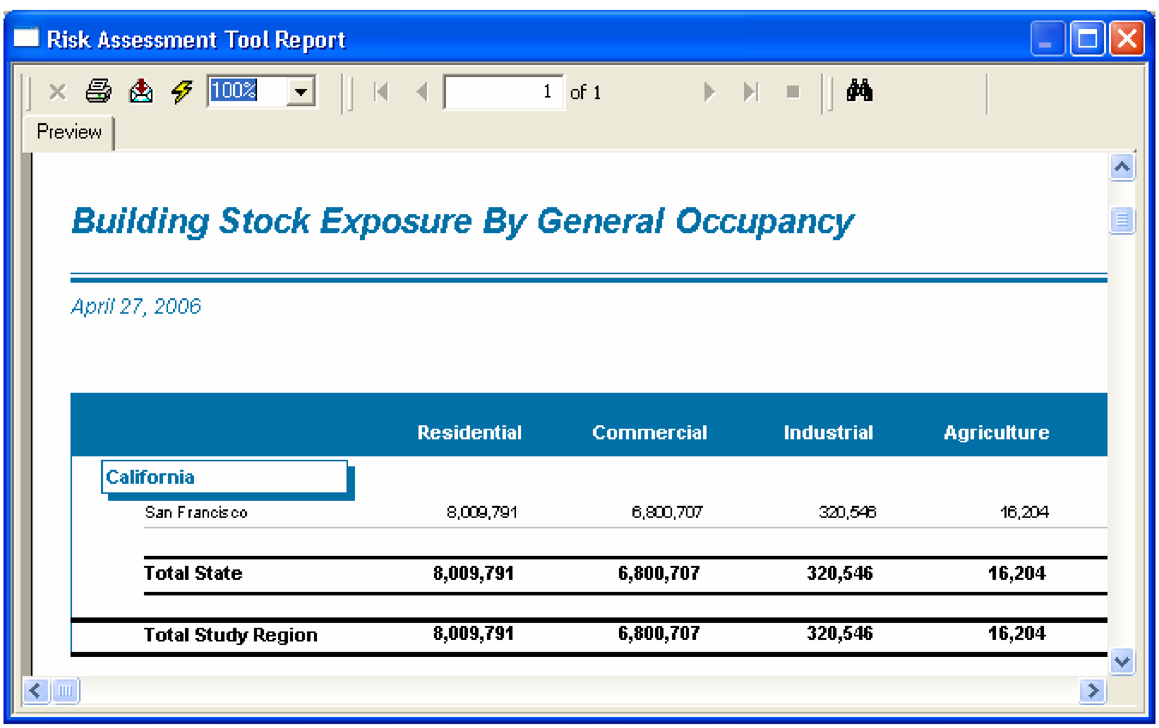
Tract	Structural Damage (thous.	Non-Structural Damage (thous. $)
06075010100	$12,814.58	$57,320.20
06075010200	$15,390.79	$68,101.16
06075010300	$5,903.57	$33,522.53
06075010400	$8,694.68	$45,536.43
06075010500	$55,927.33	$194,090.70
06075010600	$8,443.21	$43,118.91
06075010700	$11,078.69	$55,677.01
06075010800	$6,327.80	$36,977.91
06075010900	$7,207.87	$41,318.57
06075011000	$8,286.07	$42,189.30
06075011100	$12,861.18	$66,385.93
06075011200	$6,682.81	$36,805.77
06075011300	$6,219.65	$29,642.53
06075011400	$7,718.24	$33,781.33
06075011500	$19,699.39	$73,912.84
06075011700	$167,341.63	$575,672.80

A.7.10 Summary Reports

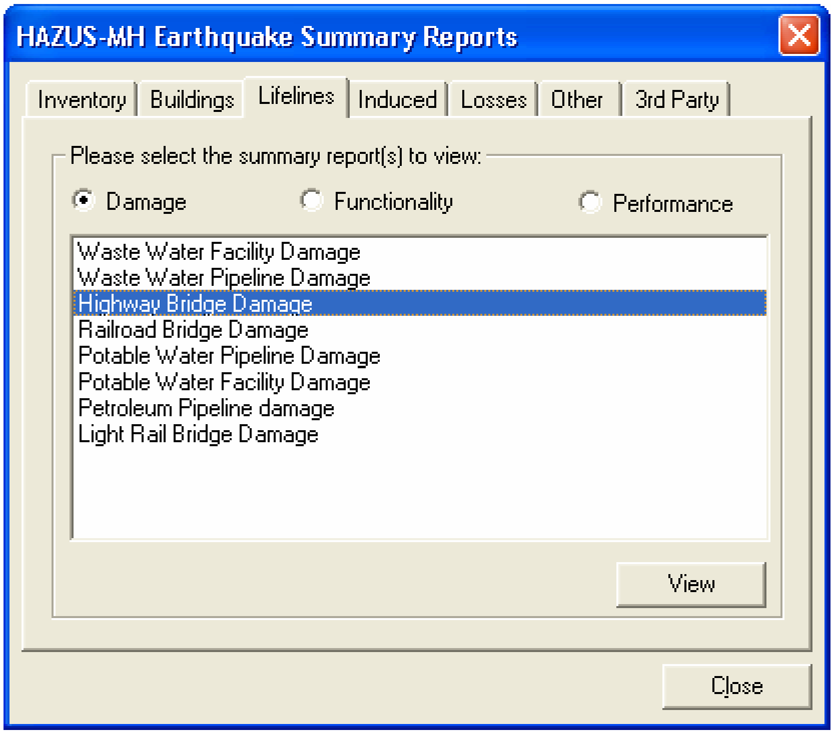
Click on the Results | Summary Reports menu option. This action will open the following dialog:

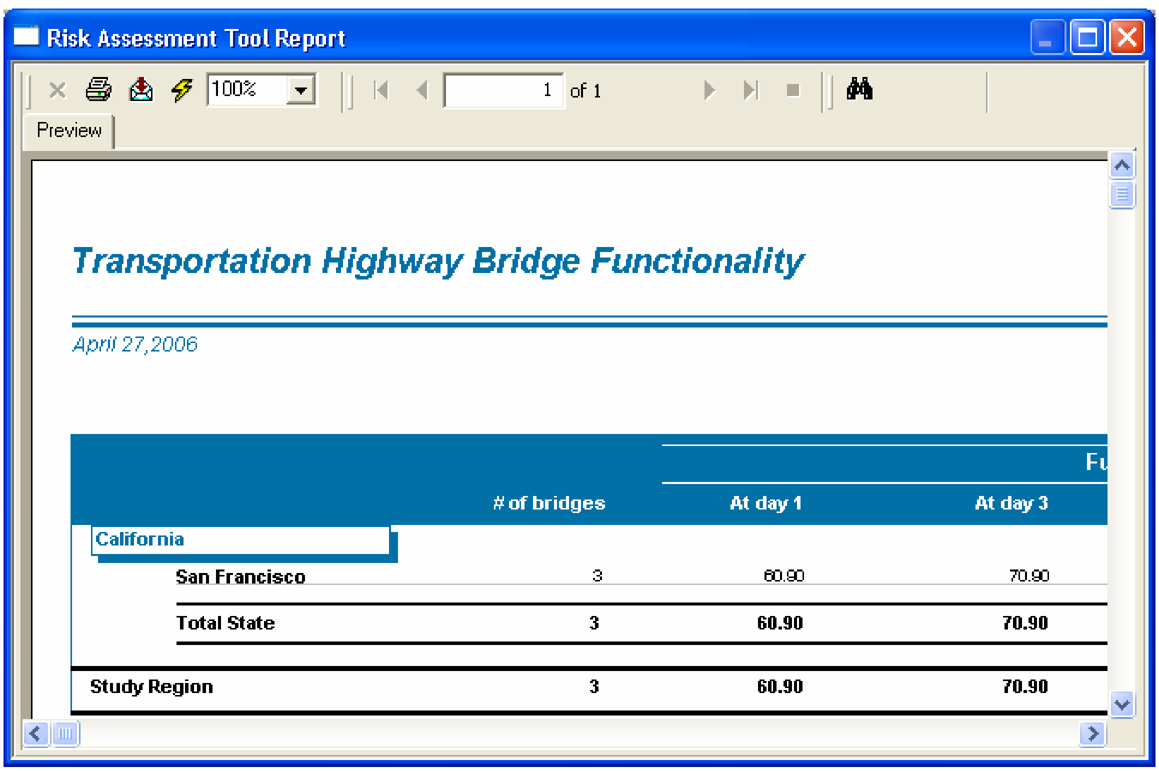


Select 'Building Stock Dollar Exposure by Occupancy' and click 'View'. Change the zoom level to 100%.



Close the summary report by clicking the 'x' in the top right corner. Back at the summary report dialog, select the 'Lifelines' tab, 'Functionality' and pick 'Highway Bridge Functionality'. Click 'View' to view the report.





This concludes the test cases for the Results menu.

A.8 Conclusion

If you have successfully completed all of the steps in the preceding sections, the Earthquake Model has been installed correctly and is functioning as intended. You may now proceed with further testing of the software.

Appendix B. Classification Systems

Table B.1 Site Classes
(from the 1997 *NEHRP Provisions*)

Site Class	Site Class Description	Shear Wave Velocity (m/sec)	
		Minimum	**Maximum**
A	HARD ROCK Eastern United States sites only	1500	
B	ROCK	760	1500
C	VERY DENSE SOIL AND SOFT ROCK Untrained shear strength $u_s \geq 2000$ psf ($u_s \geq 100$ kPa) or $N \geq 50$ blows/ft	360	760
D	STIFF SOILS Stiff soil with undrained shear strength 1000 psf $\leq u_s \leq$ 2000 psf (50 kPa $\leq u_s \leq$ 100 kPa) or $15 \leq N \leq 50$ blows/ft	180	360
E	SOFT SOILS Profile with more than 10 ft (3 m) of soft clay defined as soil with plasticity index PI > 20, moisture content w > 40% and undrained shear strength $u_s < 1000$ psf (50 kPa) (N < 15 blows/ft)		180
F	SOILS REQUIRING SITE SPECIFIC EVALUATIONS 1. Soils vulnerable to potential failure or collapse under seismic loading: e.g. liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays (10 ft (3 m) or thicker layer) 3. Very high plasticity clays: (25 ft (8 m) or thicker layer with plasticity index >75) 4. Very thick soft/medium stiff clays: (120 ft (36 m) or thicker layer)		

Table B.2 Structural Building Classifications (Model Building Types)

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1	W1	Wood, Light Frame (≤ 5,000 sq. ft.)		1 - 2	1	14
2	W2	Wood, Greater than 5,000 sq. ft.		All	2	24
3	S1L	Steel Moment Frame	Low-Rise	1 - 3	2	24
4	S1M		Mid-Rise	4 - 7	5	60
5	S1H		High-Rise	8+	13	156
6	S2L	Steel Braced Frame	Low-Rise	1 - 3	2	24
7	S2M		Mid-Rise	4 - 7	5	60
8	S2H		High-Rise	8+	13	156
9	S3	Steel Light Frame		All	1	15
10	S4L	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise	1 - 3	2	24
11	S4M		Mid-Rise	4 - 7	5	60
12	S4H		High-Rise	8+	13	156
13	S5L	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise	1 - 3	2	24
14	S5M		Mid-Rise	4 - 7	5	60
15	S5H		High-Rise	8+	13	156
16	C1L	Concrete Moment Frame	Low-Rise	1 - 3	2	20
17	C1M		Mid-Rise	4 - 7	5	50
18	C1H		High-Rise	8+	12	120
19	C2L	Concrete Shear Walls	Low-Rise	1 - 3	2	20
20	C2M		Mid-Rise	4 - 7	5	50
21	C2H		High-Rise	8+	12	120
22	C3L	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise	1 - 3	2	20
23	C3M		Mid-Rise	4 - 7	5	50
24	C3H		High-Rise	8+	12	120
25	PC1	Precast Concrete Tilt-Up Walls		All	1	15
26	PC2L	Precast Concrete Frames with Concrete Shear Walls	Low-Rise	1 - 3	2	20
27	PC2M		Mid-Rise	4 - 7	5	50
28	PC2H		High-Rise	8+	12	120
29	RM1L	Reinforced Masonry Bearing Wall s with Wood or Metal Deck Diaphragms	Low-Rise	1-3	2	20
30	RM2M		Mid-Rise	4+	5	50
31	RM2L	Reinforced Masonry Bearing Wall s with Precast Concrete Diaphragms	Low-Rise	1 - 3	2	20
32	RM2M		Mid-Rise	4 - 7	5	50
33	RM2H		High-Rise	8+	12	120
34	URML	Unreinforced Masonry Bearing Walls	Low-Rise	1 - 2	1	15
35	URMM		Mid-Rise	3+	3	35
36	MH	Mobile Homes		All	1	10

Table B.3 Building Occupancy Classes

Label	Occupancy Class	Example Descriptions
	Residential	
RES1	Single Family Dwelling	House
RES2	Mobile Home	Mobile Home
RES3	Multi Family Dwelling RES3A Duplex RES3B 3-4 Units RES3C 5-9 Units RES3D 10-19 Units RES3E 20-49 Units RES3F 50+ Units	Apartment/Condominium
RES4	Temporary Lodging	Hotel/Motel
RES5	Institutional Dormitory	Group Housing (military, college), Jails
RES6	Nursing Home	
	Commercial	
COM1	Retail Trade	Store
COM2	Wholesale Trade	Warehouse
COM3	Personal and Repair Services	Service Station/Shop
COM4	Professional/Technical Services	Offices
COM5	Banks	
COM6	Hospital	
COM7	Medical Office/Clinic	
COM8	Entertainment & Recreation	Restaurants/Bars
COM9	Theaters	Theaters
COM10	Parking	Garages
	Industrial	
IND1	Heavy	Factory
IND2	Light	Factory
IND3	Food/Drugs/Chemicals	Factory
IND4	Metals/Minerals Processing	Factory
IND5	High Technology	Factory
IND6	Construction	Office
	Agriculture	
AGR1	Agriculture	
	Religion/Non/Profit	

REL1	Church/Non-Profit	
	Government	
GOV1	General Services	Office
GOV2	Emergency Response	Police/Fire Station/EOC
	Education	
EDU1	Grade Schools	
EDU2	Colleges/Universities	Does not include group housing

Table B.4 Essential Facilities Classification

Label	Occupancy Class	Description
	Medical Care Facilities	
EFHS	Small Hospital	Hospital with less than 50 Beds
EFHM	Medium Hospital	Hospital with beds between 50 & 150
EFHL	Large Hospital	Hospital with greater than 150 Beds
EFMC	Medical Clinics	Clinics, Labs, Blood Banks
	Emergency Response	
EFFS	Fire Station	
EFPS	Police Station	
EFEO	Emergency Operation Centers	
	Schools	
EFS1	Grade Schools	Primary/ High Schools
EFS2	Colleges/Universities	

Table B.5 High Potential Loss Facilities Classification

Label	Description
	Dams
HPDE	Earth
HPDR	Rock fill
HPDG	Gravity
HPDB	Buttress
HPDA	Arch
HPDU	Multi-Arch
HPDC	Concrete
HPDM	Masonry
HPDS	Stone
HPDT	Timber Crib
HPDZ	Miscellaneous
	Nuclear Power Facilities
HPNP	Nuclear Power Facilities
	Military Installations
HPMI	Military Installations

Table B.6 Highway System Classification

Label	Description
	Highway Roads
HRD1	Major Roads
HRD2	Urban Roads
	Highway Bridges
HWB1	Major Bridge - Length > 150m (Conventional Design)
HWB2	Major Bridge - Length > 150m (Seismic Design)
HWB3	Single Span – (Not HWB1 or HWB2) (Conventional Design)
HWB4	Single Span – (Not HWB1 or HWB2) (Seismic Design)
HWB5	Concrete, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
HWB6	Concrete, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB7	Concrete, Multi-Column Bent, Simple Support (Seismic Design)
HWB8	Continuous Concrete, Single Column, Box Girder (Conventional Design)
HWB9	Continuous Concrete, Single Column, Box Girder (Seismic Design)
HWB10	Continuous Concrete, (Not HWB8 or HWB9) (Conventional Design)
HWB11	Continuous Concrete, (Not HWB8 or HWB9) (Seismic Design)
HWB12	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
HWB13	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB14	Steel, Multi-Column Bent, Simple Support (Seismic Design)
HWB15	Continuous Steel (Conventional Design)
HWB16	Continuous Steel (Seismic Design)
HWB17	PS Concrete Multi-Column Bent, Simple Support - (Conventional Design), Non-California
HWB18	PS Concrete, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB19	PS Concrete, Multi-Column Bent, Simple Support (Seismic Design)
HWB20	PS Concrete, Single Column, Box Girder (Conventional Design)
HWB21	PS Concrete, Single Column, Box Girder (Seismic Design)
HWB22	Continuous Concrete, (Not HWB20/HWB21) (Conventional Design)
HWB23	Continuous Concrete, (Not HWB20/HWB21) (Seismic Design)
HWB24	Same definition as HWB12 except that the bridge length is less than 20 meters
HWB25	Same definition as HWB13 except that the bridge length is less than 20 meters
HWB26	Same definition as HWB15 except that the bridge length is less than 20 meters and Non-CA
HWB27	Same definition as HWB15 except that the bridge length is less than 20 meters and in CA
HWB28	All other bridges that are not classified (including wooden bridges)
	Highway Tunnels
HTU1	Highway Bored/Drilled Tunnel
HTU2	Highway Cut and Cover Tunnel

Table B.7 Railway System Classification

Label	Description
	Railway Tracks
RTR1	Railway Tracks
	Railway Bridges
RLB1	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
RLB2	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
RLB3	Steel, Multi-Column Bent, Simple Support (Seismic Design)
RLB4	Continuous Steel (Conventional Design)
RLB5	Continuous Steel (Seismic Design)
RLB6	Same definition as HWB1 except that the bridge length is less than 20 meters
RLB7	Same definition as HWB2 except that the bridge length is less than 20 meters
RLB8	Same definition as HWB4 except that the bridge length is less than 20 meters and Non-CA
RLB9	Same definition as HWB5 except that the bridge length is less than 20 meters and in CA
RLB10	All other bridges that are not classified
	Railway Urban Station
RST	Rail Urban Station (with all building type options enabled)
	Railway Tunnels
RTU1	Rail Bored/Drilled Tunnel
RTU2	Rail Cut and Cover Tunnel
	Railway Fuel Facility
RFF	Rail Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
	Railway Dispatch Facility
RDF	Rail Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
	Railway Maintenance Facility
RMF	Rail Maintenance Facility (with all building type options enabled)

Table B.8 Light Rail System Classification

Label	Description
	Light Rail Tracks
LTR1	Light Rail Track
	Light Rail Bridges
LRB1	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
LRB2	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
LRB3	Steel, Multi-Column Bent, Simple Support (Seismic Design)
LRB4	Continuous Steel (Conventional Design)
LRB5	Continuous Steel (Seismic Design)
LRB6	Same definition as HWB1 except that the bridge length is less than 20 meters
LRB7	Same definition as HWB2 except that the bridge length is less than 20 meters
LRB8	Same definition as HWB4 except that the bridge length is less than 20 meters and Non-CA
LRB9	Same definition as HWB5 except that the bridge length is less than 20 meters and in CA
LRB10	All other bridges that are not classified
	Light Rail Tunnels
LTU1	Light Rail Bored/Drilled Tunnel
LTU2	Light Rail Cut and Cover Tunnel
	DC Substation
LDC1	Light Rail DC Substation w/ Anchored Sub-Components
LDC2	Light Rail DC Substation w/ Unanchored Sub-Components
	Dispatch Facility
LDF	Light Rail Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
	Maintenance Facility
LMF	Maintenance Facility (with all building type options enabled)

Table B.9 Bus System Classification

Label	Description
	Bus Urban Station
BPT	Bus Urban Station (with all building type options enabled)
	Bus Fuel Facility
BFF	Bus Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
	Bus Dispatch Facility
BDF	Bus Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
	Bus Maintenance Facility
BMF	Bus Maintenance Facilities (with all building type options enabled)

Table B.10 Port and Harbor System Classification

Label	Description
	Waterfront Structures
PWS	Waterfront Structures
	Cranes/Cargo Handling Equipment
PEQ1	Stationary Port Handling Equipment
PEQ2	Rail Mounted Port Handling Equipment
	Warehouses
PWH	Port Warehouses (with all building type options enabled)
	Fuel Facility
PFF	Port Fuel Facility Facility (different combinations for with or without anchored components and/or with or without backup power)

Table B.11 Ferry System Classification

Label	Description
	Water Front Structures
FWS	Ferry Waterfront Structures
	Ferry Passenger Terminals
FPT	Passenger Terminals (with all building type options enabled)
	Ferry Fuel Facility
FFF	Ferry Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
	Ferry Dispatch Facility
FDF	Ferry Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
	Ferry Maintenance Facility
FMF	Piers and Dock Facilities (with all building type options enabled)

Table B.12 Airport System Classification

Label	Description
	Airport Control Towers
ACT	Airport Control Tower (with all building type options enabled)
	Airport Terminal Buildings
ATB	Airport Terminal Building (with all building type options enabled)
	Airport Parking Structures
APS	Airport Parking Structure (with all building type options enabled)
	Fuel Facilities
AFF	Airport Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
	Airport Maintenance & Hangar Facility
AMF	Airport Maintenance & Hangar Facility (with all building type options enabled)
ARW	Airport Runway
	Airport Facilities - Others
AFO	Gliderport, Seaport, Stolport, Ultralight or Baloonport Facilities
AFH	Heliport Facilities

Table B.13 Potable Water System Classification

Label	Description
	Pipelines
PWP1	Brittle Pipe
PWP2	Ductile Pipe
	Pumping Plants
PPPL	Large Pumping Plant (> 50 MGD) [different combinations for with or without anchored components]
PPPM	Medium Pumping Plant (10 to 50 MGD) [different combinations for with or without anchored components]
PPPS	Small Pumping Plant (< 10 MGD) [different combinations for with or without anchored components]
	Wells
PWE	Wells
	Water Storage Tanks (Typically, 0.5 MGD to 2 MGD)
PSTAS	Above Ground Steel Tank
PSTBC	Buried Concrete Tank
PSTGC	On Ground Concrete Tank
PSTGS	On Ground Steel Tank
PSTGW	On Ground Wood Tank
	Water Treatment Plants
PWTL	Large WTP (> 200 MGD) [different combinations for with or without anchored components]
PWTM	Medium WTP (50-200 MGD) [different combinations for with or without anchored components]
PWTS	Small WTP (< 50 MGD) [different combinations for with or without anchored components]

Table B.14 Waste Water System Classification

Label	Description
	Buried Pipelines
WWP1	Brittle Pipe
WWP2	Ductile Pipe
	Waste Water Treatment Plants
WWTL	Large WWTP (> 200 MGD) [different combinations for with or without anchored components]
WWTM	Medium WWTP (50-200 MGD) [different combinations for with or without anchored components]
WWTS	Small WWTP (< 50 MGD) [different combinations for with or without anchored components]
	Lift Stations
WLSL	Large Lift Stations (> 50 MGD) [different combinations for with or without anchored components]
WLSM	Medium Lift Stations (10 MGD - 50 MGD) [different combinations for with or without anchored components]
WLSS	Small Lift Stations (< 10 MGD) [different combinations for with or without anchored components]

Table B.5 Oil System Classification

Label	Description
	Pipelines
OIP1	Welded Steel Pipe with Gas Welded Joints
OIP2	Welded Steel Pipe with Arc Welded Joints
	Refineries
ORFL	Large Refinery (> 500,000 lb./day) [different combinations for with or without anchored components]
ORFM	Medium Refinery (100,000 - 500,000 lb./ day) [different combinations for with or without anchored components]
ORFS	Small Refinery (< 100,000 lb./day) [different combinations for with or without anchored components]
	Pumping Plants
OPP	Pumping Plant [different combinations for with or without anchored components]
	Tank Farms
OTF	Tank Farms with Anchored Tanks [different combinations for with or without anchored components]

Table B.16 Natural Gas System Classification

Label	Description
	Buried Pipelines
NGP1	Welded Steel Pipe with Gas Welded Joints
NGP2	Welded Steel Pipe with Arc Welded Joints
	Compressor Stations
NGC	Compressor Stations [different combinations for with or without anchored components]

Table B.17 Electric Power System Classification

Label	Description
	Transmission Substations
ESSL	Low Voltage (115 KV) Substation [different combinations for with or without anchored components]
ESSM	Medium Voltage (230 KV) Substation [different combinations for with or without anchored components]
ESSH	High Voltage (500 KV) Substation [different combinations for with or without anchored components]
	Distribution Circuits
EDC	Distribution Circuits (either Seismically Designed Components or Standard Components)
	Generation Plants
EPPL	Large Power Plants (> 500 MW) [different combinations for with or without anchored components]
EPPM	Medium Power Plants (100 - 500 MW) [different combinations for with or without anchored components]
EPPS	Small Power Plants (< 100 MW) [different combinations for with or without anchored components]

Table B.18 Communication Classification

Label	Description
	Central Offices
CCO	Central Offices (different combinations for with or without anchored components and/or with or without backup power)
	Stations or Transmitters
CBR	AM or FM radio stations or transmitters
CBT	TV stations or transmitters
CBW	Weather stations or transmitters
CBO	Other stations or transmitters

Table B.19 Mapping of Standard Industrial Codes to NIBS Occupancy Classes

Label	Occupancy Class	Standard Industrial Codes (SIC)
	Residential	
RES1	Single Family Dwelling	
RES2	Mobile Home	
RES3	Multi Family Dwelling	
RES4	Temporary Lodging	70
RES5	Institutional Dormitory	
RES6	Nursing Home	8051, 8052, 8059
	Commercial	
COM1	Retail Trade	52, 53, 54, 55, 56, 57, 59
COM2	Wholesale Trade	42, 50, 51
COM3	Personal and Repair Services	72, 75, 76, 83, 88
COM4	Business/Professional/Technical Services	40, 41, 44, 45, 46, 47, 49, 61, 62, 63, 64, 65, 67, 73, 78 (except 7832), 81, 87, 89
COM5	Depository Institutions	60
COM6	Hospital	8062, 8063, 8069
COM7	Medical Office/Clinic	80 (except 8051, 8052, 8059, 8062, 8063, 8069)
COM8	Entertainment & Recreation	48, 58, 79 (except 7911), 84
COM9	Theaters	7832, 7911
COM10	Parking	
	Industrial	
IND1	Heavy	22, 24, 26, 32, 34, 35 (except 3571, 3572), 37
IND2	Light	23, 25, 27, 30, 31, 36 (except 3671, 3672, 3674), 38, 39
IND3	Food/Drugs/Chemicals	20, 21, 28, 29
IND4	Metals/Minerals Processing	10, 12, 13, 14, 33
IND5	High Technology	3571, 3572, 3671, 3672, 3674
IND6	Construction	15, 16, 17
	Agriculture	
AGR1	Agriculture	01, 02, 07, 08, 09
	Religion/Non-Profit	
REL1	Church/Membership Organizations	86
	Government	
GOV1	General Services	43, 91, 92 (except 9221, 9224) , 93, 94, 95, 96, 97
GOV2	Emergency Response	9221, 9224
	Education	
EDU1	Schools/Libraries	82 (except 8221, 8222)
EDU2	Colleges/Universities	8221, 8222

Appendix C. Descriptions of Model Building Types

Table C.1 lists 36 model building types which have been defined for the methodology. The classification system is based on the classification system of FEMA-178 (1992). By reviewing the table it can be seen that there are 16 basic building types (shown in bold) with some building types being subdivided with respect to height. Each basic building class is defined by a short description of its structural system. These descriptions are based on FEMA-178 and follow Table C.1.

Table C.1 Structural Building Classifications (Model Building Types)

No.	Label	Description	Heigh t
1	W1	Wood, Light Frame (W1)	ALL
2	W2	Wood, Commercial and Industrial (W2)	ALL
		Steel Moment Frame (S1)	
3	S1L	Low-Rise	1-3
4	S1M	Mid-Rise	4-7
5	S1H	High-Rise	8+
		Steel Braced Frame (S2)	
6	S2L	Low-Rise	1-3
7	S2M	Mid-Rise	4-7
8	S2H	High-Rise	8+
9	S3	Steel Light Frame (S3)	
		Steel Frame w/ Cast-in-Place Concrete Shear Walls (S4)	
10	S4L	Low-Rise	1-3
11	S4M	Mid-Rise	4-7
12	S4H	High-Rise	8+
		Steel Frame w/ Unreinforced Masonry Infill Walls (S5)	
13	S5L	Low-Rise	1-3
14	S5M	Mid-Rise	4-7
15	S5H	High-Rise	8+
		Reinforced Concrete Moment Resisting Frame (C1)	
16	C1L	Low-Rise	1-3
17	C1M	Mid-Rise	4-7
18	C1H	High-Rise	8+
		Concrete Shear Walls (C2)	
19	C2L	Low-Rise	1-3
20	C2M	Mid-Rise	4-7
21	C2H	High-Rise	8+
		Concrete Frame Buildings w/ Unreinforced Masonry Infill Walls (C3)	
22	C3L	Low-Rise	1-3
23	C3M	Mid-Rise	4-7
24	C3H	High-Rise	8+

Table C.1 Cont. Structural Building Classifications (Model Building Types)

No.	Label	Description	Height
		Precast-Concrete Tilt-Up Walls (PC1)	
25	PC1	Low-Rise	ALL
		Precast Concrete Frames w/ Concrete Shear Walls (PC2)	
26	PC2L	Low-Rise	1-3
27	PC2M	Mid-Rise	4-7
28	PC2H	High-Rise	8+
		Reinforced Masonry Bearing Walls w/ Wood or Metal Deck	
29	RM1L	Low-Rise	1-3
30	RM1M	Mid-Rise	4+
		Reinforced Masonry Bearing Walls w/ Precast Concrete	
31	RM2L	Low-Rise	1-3
32	RM2M	Mid-Rise	4-7
33	RM2H	High-Rise	8+
		Unreinforced Masonry Bearing Walls (URM)	
34	URML	Low-Rise	1-2
35	URMM	Mid-Rise	3+
36	MH	Mobile Home (MH)	

C.1 Wood, Light Frame (W1):

These are typically single- or multiple-family dwellings. The essential structural feature of these buildings is repetitive framing by wood rafters or joists on wood stud walls. Loads are light and spans are small. These buildings may have relatively heavy masonry chimneys and may be partially or fully covered with masonry veneer. Most of these buildings, especially the single-family residences, are not engineered but constructed in accordance with "conventional construction" provisions of building codes. Hence, they usually have the components of a lateral-force-resisting system even though it may be incomplete. Lateral loads are transferred by diaphragms to shear walls. The diaphragms are roof panels and floors which may be sheathed with wood, plywood or fiberboard sheathing. Shear walls are exterior walls sheathed with boards, stucco, plaster, plywood, gypsum board, particle board, or fiberboard, or interior partition walls sheathed with plaster or gypsum board.

C.2 Wood, Commercial and Industrial (W2):

These buildings usually are commercial or industrial buildings with a floor area of 5,000 square feet or more and with few, if any, interior walls. The essential structural character of these buildings is framing by beams or major horizontally spanning members over columns. These horizontal members may be glued-laminated (glu-lam) wood, solid-sawn wood beams, or wood trusses, or steel beams, or trusses. Lateral loads usually are resisted by wood diaphragms and exterior walls sheathed with plywood, stucco, plaster, or other paneling. The walls may have diagonal rod bracing. Large openings for storefronts and garages often require post-and-beam framing. Lateral load resistance on those lines may be achieved with steel rigid frames (moment frames) or diagonal bracing.

C.3 Steel Moment Frame (S1):

These buildings have a frame of steel columns and beams. In some cases, the beam-column connections have very small moment resisting capacity but, in other cases, some of the beams and columns are fully developed as moment frames to resist lateral forces. Usually the structure is concealed on the outside by exterior walls, which can be of almost any material (curtain walls, brick masonry, or precast concrete panels), and on the inside by ceilings and column furring. Lateral loads are transferred by diaphragms to moment resisting frames. The diaphragms can be almost any material. The frames develop their stiffness by full or partial moment connections. The frames can be located almost anywhere in the building. Usually the columns have their strong directions oriented so that some columns act primarily in one direction while the others act in the other direction. Steel moment frame buildings are typically more flexible than shear wall buildings. This low stiffness can result in large interstory drifts that may lead to relatively greater nonstructural damage.

C.4 Steel Braced Frame (S2):

These buildings are similar to steel moment frame buildings except that the vertical components of the lateral-force-resisting system are braced frames rather than moment frames.

C.5 Steel Light Frame (S3):

These buildings are pre-engineered and prefabricated with transverse rigid frames. The roof and walls consist of lightweight panels, usually corrugated metal. The frames are designed for maximum efficiency, often with tapered beam and column sections built up of light steel plates. The frames are built in segments and assembled in the field with bolted joints. Lateral loads in the transverse direction are resisted by the rigid frames with loads distributed to them by diaphragm elements, typically rod-braced steel roof framing bays. Loads in the longitudinal direction are resisted entirely by shear elements which can be either the roof and wall sheathing panels, an independent system of tension-only rod bracing, or a combination of panels and bracing.

C.6 Steel Frame with Cast-In-Place Concrete Shear Walls (S4):

The shear walls in these buildings are cast-in-place concrete and may be bearing walls. The steel frame is designed for vertical loads only. Lateral loads are transferred by diaphragms of almost any material to the shear walls. The steel frame may provide a secondary lateral-force-resisting system depending on the stiffness of the frame and the moment capacity of the beam-column connections. In modern “dual” systems, the steel moment frames are designed to work together with the concrete shear walls in proportion to their relative rigidities.

C.7 Steel Frame with Unreinforced Masonry Infill Walls (S5):

This is one of the older types of buildings. The infill walls usually are offset from the exterior frame members, wrap around them, and present a smooth masonry exterior with no indication of the frame. Solidly infilled masonry panels, when they fully engage the surrounding frame members (i.e. lie in the same plane), provide stiffness and lateral load resistance to the structure.

C.8 Reinforced Concrete Moment Resisting Frames (C1):

These buildings are similar to steel moment frame buildings except that the frames are reinforced concrete. There is a large variety of frame systems. Some older concrete frames may be proportioned and detailed such that brittle failure of the frame members can occur in earthquakes, leading to partial or full collapse of the buildings. Modern frames in zones of high seismicity are proportioned and detailed for ductile behavior and are likely to undergo large deformations during an earthquake without brittle failure of frame members and collapse.

C.9 Concrete Shear Walls (C2):

The vertical components of the lateral-force-resisting system in these buildings are concrete shear walls that are usually bearing walls. In older buildings, the walls often are quite extensive and the wall stresses are low but reinforcing is light. In newer buildings, the shear walls often are limited in extent, thus generation concerns about boundary members and overturning forces.

C.10 Concrete Frame Buildings with Unreinforced Masonry Infill Walls (C3):

These buildings are similar to steel frame buildings with unreinforced masonry infill walls except that the frame is of reinforced concrete. In these buildings, the shear strength of the columns, after cracking of the infill, may limit the semiductile behavior of the system.

C.11 Precast Concrete Tilt-Up Walls (PC1):

These buildings have a wood or metal deck roof diaphragm, which often is very large, that distributes lateral forces to precast concrete shear walls. The walls are thin but relatively heavy while the roofs are relatively light. Older buildings often have inadequate connections for anchorage of the walls to the roof for out-of-plane forces, and the panel connections often are brittle. Tilt-up buildings usually are one or two stories in height. Walls can have numerous openings for doors and windows of such size that the wall looks more like a frame than a shear wall.

C.12 Precast Concrete Frames with Concrete Shear Walls (PC2):

These buildings contain floor and roof diaphragms typically composed of precast concrete elements with or without cast-in-place concrete topping slabs. The diaphragms are supported by precast concrete girders and columns. The girders often bear on column corbels. Closure strips between precast floor elements and beam-column joints usually are cast-in-place concrete. Welded steel inserts often are used to interconnect precast elements. Lateral loads are resisted by precast or cast-in-place concrete shear walls. For buildings with precast frames and concrete shear walls to perform well, the details used to connect the structural elements must have sufficient strength and displacement capacity; however, in some cases, the connection details between the precast elements have negligible ductility.

C.13 Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms (RM1):

These buildings have perimeter bearing walls of reinforced brick or concrete-block masonry. These walls are the vertical elements in the lateral-force-resisting system. The floors and roofs are framed either with wood joists and beams with plywood or straight or diagonal sheathing, or with steel beams with metal deck with or without a concrete fill. Wood floor framing is supported by interior wood posts or steel columns; steel beams are supported by steel columns.

C.14 Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms (RM2):

These buildings have bearing walls similar to those of reinforced masonry bearing wall structures with wood or metal deck diaphragms, but the roof and floors are composed of precast concrete elements such as planks or tee-beams and the precast roof and floor elements are supported on interior beams and columns of steel or concrete (cast-in-place or precast). The precast horizontal elements often have a cast-in-place topping.

C.15 Unreinforced Masonry Bearing Walls (URM):

These buildings include structural elements that vary depending on the building's age and, to a lesser extent, its geographic location. In buildings built before 1900, the majority of floor and roof construction consists of wood sheathing supported by wood subframing. In large multistory buildings, the floors are cast-in-place concrete supported by the unreinforced masonry walls and/or steel or concrete interior framing. In unreinforced masonry constructed after 1950 wood floors usually have plywood rather than board sheathing. In regions of lower seismicity, buildings of this type constructed more recently can include floor and roof framing that consists of metal deck and concrete fill supported by steel framing elements. The perimeter walls, and possibly some interior walls, are unreinforced masonry. The walls may or may not be anchored to the diaphragms. Ties between the walls and diaphragms are more common for the bearing walls than for walls that are parallel to the floor framing. Roof ties usually are less common and more erratically spaced than those at the floor levels. Interior partitions that interconnect the floors and roof can have the effect of reducing diaphragm displacements.

C.16 Mobile Homes (MH):

These are prefabricated housing units that are trucked to the site and then placed on isolated piers, jackstands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of mobile homes usually are constructed with plywood and outside surfaces are covered with sheet metal.

Appendix D. Description of Lifeline Components

D.1 Highway Transportation System

Below is a list of highway components which have been defined for the methodology. The list indicates the 3 basic components of the transportation system. Some of these components are subdivided further.

- Highway Roads
- Highway Bridges
- Highway Tunnels

D.1.1 Highway Roads

Highway roads are classified as major roads and urban roads. Major roads include interstate and state highways and other roads with four lanes or more. Parkways are also classified as major roads. Urban roads include inter-city roads and other roads with two lanes.

D.1.2 Bridges

Bridges are classified based on the following structural characteristics:

- Seismic Design
- Number of spans: single vs. multiple span bridges
- Structure type: concrete, steel, others
- Pier type: multiple column bents, single column bents and pier walls
- Abutment type and bearing type: monolithic vs. non-monolithic; high rocker bearings, low steel bearings and neoprene rubber bearings
- Span continuity: continuous, discontinuous (in-span hinges), simply supported.
- The seismic design of a bridge is taken into account in terms of the (*i*) spectrum modification factor, (*ii*) strength reduction factor due to cyclic motion, (*iii*) drift limits, and (*iv*) the longitudinal reinforcement ratio.

This classification scheme incorporates various parameters that affect damage into fragility analysis and provides a means to obtain better fragility curves when data become available.

D.1.3 Tunnels

Tunnels are classified as:

- Bored/Drilled
- Cut & Cover

D.2 Railway Transportation System

Below is a list of railway components which have been defined for the methodology. By reviewing the list it can be seen that there are 7 basic components (shown in bold) with some being subdivided. Each component is defined by a short description below.

- Railway Tracks
- Railway Bridges
- Railway Tunnels
- Railway Urban Station
- Railway Fuel Facility
- Railway Dispatch Facility
- Railway Maintenance Facility

D.2.1 Tracks

The class Railway Tracks refers to the assembly of rails, ties, and fastenings, and the ground on which they rest. Only one classification is adopted for these components.

D.2.2 Bridges

The classes of railway bridges are considered analogous to those of major bridges in highway systems. That is they are considered to have at least one span greater than 500 feet. Railway bridges are classified based on the design criteria adopted in the design of these bridges.

- • Seismically designed/retrofitted bridges
- These bridges are either designed with seismic considerations or were retrofitted to comply with the seismic provisions.
- • Conventionally designed bridges
- These bridges are designed without taking seismic considerations into account.

D.2.3 Tunnels

Tunnels are classified as

- Bored/Drilled
- Cut & Cover

D.2.4 Railway System Facilities

- Railway system facilities include urban and suburban stations, maintenance facilities, fuel facilities, and dispatch facilities.
- **Urban and Suburban stations** are generally key connecting hubs that are important for system functionality. In the western U.S., these buildings are mostly made of reinforced concrete shear walls or moment resisting steel frames, while in the eastern U.S., the small stations are mostly wood and the large ones are mostly masonry or braced steel frames.
- **Fuel facilities** include buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment and with or without backup power (all combinations), and fuel facilities with buried tanks.
- **Dispatch facilities** consist of buildings, backup power supplies (if available, anchored or unanchored diesel generators), and electrical equipment (anchored or unanchored). In total, four types of dispatch facilities are considered. These are dispatch facilities with or without anchored equipment and with or without backup power (all combinations).
- **Maintenance facilities** are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are often low-rise steel braced frames.

D.3 Light Railway Transportation System

A light rail system consists mainly of six components: tracks, bridges, tunnels, maintenance facilities, dispatch facilities, and DC power substations. These components are listed below.

- Light Rail Tracks
- Light Rail Bridges
- Light Rail Tunnels
- DC Substation
- Dispatch Facility
- Maintenance Facility

D.3.1 Tracks

The class Light Rail Tracks refers to the assembly of rails, ties, and fastenings, and the ground on which they rest. Only one classification is adopted for these components.

D.3.2 Bridges

The classes of light rail bridges are considered analogous to those of bridges in highway systems. Light rail bridges are classified based on the design criteria adopted in the design of these bridges.

- • Seismically designed/retrofitted bridges

These bridges are either designed with seismic considerations or were retrofitted to comply with the seismic provisions.

- • Conventionally designed bridges

These bridges are designed without taking seismic considerations into account.

D.3.3 Tunnels

Tunnels are classified as

- Bored/Drilled
- Cut & Cover

D.3.4 Railway System Facilities

Railway system facilities include DC power substations, dispatch facilities, and maintenance facilities.

- **DC Power Substations** provide DC power used by the light rail electrical distribution system. Light rail systems have low voltage DC power which consists of electrical equipment that converts the local electric utility AC power to DC power. Two types of DC power stations are considered. These are DC power stations with anchored components and DC power stations with unanchored components.
- **Dispatch facilities** consist of buildings, backup power supplies (if available, anchored or unanchored diesel generators), and electrical equipment (anchored or unanchored). In total, four types of dispatch facilities are considered. These are dispatch facilities with or without anchored equipment and with or without backup power (all combinations).
- **Maintenance facilities** are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are often low-rise steel braced frames.

D.4 Bus Transportation System

A bus system consists mainly of four basic components: urban stations, fuel facilities, dispatch facilities, and maintenance facilities. These components are listed below.

- Bus Urban Station
- Bus Fuel Facility
- Bus Dispatch Facility
- Bus Maintenance Facility

D.4.1 Urban and Suburban Stations

Urban and suburban stations are generally key connecting hubs that are important for system functionality. In the western U.S., these buildings are mostly made of reinforced concrete shear walls or moment resisting steel frames, while in the eastern U.S., the small stations are mostly wood and the large ones are mostly masonry or braced steel frames.

D.4.2 Bus System Fuel Facilities

A fuel facility includes buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment and with or without backup power (all combinations), and fuel facilities with buried tanks.

D.4.3 Bus System Dispatch Facilities

Dispatch facilities consist of buildings, backup power supplies (if available, anchored or unanchored diesel generators), and electrical equipment (anchored or unanchored). In total, four types of dispatch facilities are considered. These are dispatch facilities with or without anchored equipment and with or without backup power (all combinations).

D.4.4 Bus System Maintenance Facilities

Maintenance facilities for bus systems are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are mostly low-rise steel braced frames.

D.5 Port Transportation Systems

A port system consists of four basic components: waterfront structures, cranes/cargo handling equipment, warehouses and fuel facilities as listed below. This section provides a brief description of each.

- Waterfront Structures
- Cranes/Cargo Handling Equipment
- Warehouses
- Fuel Facility

D.5.1 Waterfront Structures

This component includes the wharf, seawalls, and piers that exist in the port system. Waterfront structures typically are supported by wood, steel or concrete piles. Many also have batter piles to resist lateral loads from wave action and impact of vessels. Seawalls are caisson walls retaining earth fill material.

D.5.2 Cranes and Cargo Handling Equipment

These are large equipment items used to load and unload freight from vessels. These can be stationary or mounted on rails.

D.5.3 Port Fuel Facilities

Fuel facilities include buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment and with or without backup power (all combinations), and fuel facilities with buried tanks.

D.5.4 Warehouses

Warehouses are large buildings usually constructed of structural steel. In some cases, warehouses may be several hundred feet from the shoreline, while in other instances, they may be located on the wharf itself.

D.6 Ferry Transportation System

A ferry system consists of five components: waterfront structures, passenger terminals, fuel facilities, dispatch facilities, and maintenance facilities. This section provides a brief description of each.

- Water Front Structures
- Ferry Passenger Terminals
- Ferry Fuel Facility
- Ferry Dispatch Facility
- Ferry Maintenance Facility

D.6.1 Waterfront Structures

The waterfront structures are located at the points of disembarkation, and they are similar to, although not as extensive as, those of the port transportation system. In some cases the ferry system may be located within the boundary of the port transportation system. The points of disembarkation are located some distance apart from one another, usually on opposite shorelines. The waterfront structures include hydraulic sandfill placement poles and/or piled dock structures.

D.6.2 Passenger Terminals

D.6.3 Fuel and Maintenance Facilities

Fuel and maintenance facilities are usually located at one of the two points of disembarkation. The size of the fuel facility is smaller than that of the port facility. Maintenance facilities are mainly steel braced frame structures.

D.6.4 Dispatch Facilities

In many cases, the dispatch facility is located in the maintenance facility or one of the passenger terminals.

D.7 Airport Transportation System

An airport system consists of six components: control tower, runways, terminal buildings, parking structures, fuel facilities, and maintenance facilities. This section provides a brief description of each.

- Airport Control Towers
- Airport Runways
- Airport Terminal Buildings
- Airport Parking Structures
- Fuel Facilities
- Airport Maintenance & Hangar Facility

D.7.1 Control Tower

The control tower consists of a building and the necessary equipment for air control and monitoring.

D.7.2 Runways

This component consists of well paved "flat and wide surfaces".

D.7.3 Terminal Buildings

These are similar to railway urban stations in that many of the functions performed and services provided to passengers are similar. These are usually constructed of structural steel or reinforced concrete.

D.7.4 Fuel Facilities

A fuel facility includes buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment and with or without backup power (all combinations), and fuel facilities with buried tanks.

D.7.5 Maintenance Facilities, Hangar Facilities, and Parking Structures

Maintenance facilities are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are mostly low-rise steel braced frames. Hangar facilities and parking structures are usually constructed of structural steel or reinforced concrete.

D.8 Potable Water System

A potable water system typically consists of transmission and distribution pipelines, water treatment plants, wells, storage tanks pumping plants, as listed below. In addition the system consists of terminal reservoirs. In this subsection, a brief description of each of these components is presented.

- Pipelines
- Water Treatment Plants
- Wells
- Water Storage Tanks (Typically, 0.5 MGD to 2 MGD)
- Pumping Plants

D.8.1 Pipelines

- **Transmission Aqueducts:** These transmission conduits are typically large size pipes more than 20 inches in diameter or channels (canals) that convey water from the source such as a reservoir, lake, river to the treatment plant. Transmission pipelines are commonly made of concrete, ductile iron, cast iron, or steel. These could be elevated, at-grade or buried. Elevated or at-grade pipes are typically made of steel (welded or riveted), and they can run in single or multiple lines. Canals are typically lined with concrete, mainly to avoid excessive loss of water by seepage and to control erosion. In addition to concrete lining, expansion joints are usually used to account for swelling and shrinkage under varying temperature and moisture conditions. Damageability of channels is not considered in the loss estimation methodology.
- **Distribution Facilities and Distribution Pipes:** Distribution of water can be accomplished by gravity, or by pumps in conjunction with on-line storage. Except for storage reservoirs located at a much higher elevation than the area being served, distribution of water would necessitate, at least, some pumping along the way. Typically, water is pumped at a relatively constant rate, with flow in excess of consumption being stored in elevated storage tanks. The stored water provides a reserve for fire flow and may be used for general-purpose flow should the electric power fail, or in case of pumping capacity loss.

Distribution pipelines are commonly made of concrete (prestressed or reinforced), asbestos cement, ductile iron, cast iron, steel, or plastic. The selection of material type and pipe size are based on the desired carrying capacity, availability of material, durability, and cost. Distribution pipes represent the network that delivers water to consumption areas. Distribution pipes may be further subdivided into primary lines, secondary lines, and small distribution mains. The primary or arterial mains carry flow from the pumping station to and from elevated storage tanks, and to the consumption areas, whether residential, industrial, commercial, or public. These lines are typically laid out in interlocking loops, and all smaller lines connecting to them are typically valved so that failure in smaller lines does not require shutting off the larger. Primary lines can be up to 36 inches in diameter. Secondary lines are smaller loops within the primary mains and run from one primary line to another. They serve to provide a large amount of water for fire fighting without excessive pressure loss. Small distribution lines represent the mains that supply water to the user and to the fire hydrants.

In this earthquake loss estimation study, the simplified method for water system network performance evaluation applies to a distribution pipe network digitized at the primary level.

D.8.2 Supply Facilities- Water Treatment Plants (WTP)

Water treatment plants are generally composed of a number of physical and chemical unit processes connected in series, for the purpose of improving the water quality. A conventional WTP consists of a coagulation process, followed by a sedimentation process, and finally a filtration process. Alternately, a WTP can be regarded as a system of interconnected pipes, basins, and channels through which the water moves, and where the flow is governed by hydraulic principles. WTP are categorized as follows:

- ***Small water treatment plants***, with capacity ranging from 10 mgd to 50 mgd, are assumed to consist of a filter gallery with flocculation tanks (composed of paddles and baffles) and settling (or sedimentation) basins as main components, chemical tanks (needed in the coagulation and other destabilization processes), a chlorination tank, electrical and mechanical equipment, and elevated pipes.
- ***Medium water treatment plants***, with capacity ranging from 50 mgd to 200 mgd, are also assumed to consist of a filter gallery with flocculation tanks (composed of paddles and baffles) and settling (or sedimentation) basins as main components, chemical tanks (needed in the coagulation and other destabilization processes), a chlorination tank, electrical and mechanical equipment, and elevated pipes.
- ***Large water treatment plants***, with capacity above 200 mgd, are simulated by adding even more redundancy to small treatment plants (i.e., three times as many flocculation, sedimentation, chemical and chlorination tanks/basins).

Water treatment plants are also classified based on whether the subcomponents (equipment and backup power) are anchored or not.

D.8.3 Wells (WE)

Wells typically have a capacity between 1 and 5 mgd. Wells are used in many cities as a primary or supplementary source of water supply. Wells include a shaft from the surface down to the aquifer, a pump to bring the water up to the surface, equipment used to treat the water, and sometimes a building which encloses the well and equipment.

D.8.4 Water Storage Tanks (ST)

Water storage tanks can be elevated steel, on-ground steel (anchored/unanchored), on-ground concrete (anchored/unanchored), buried concrete, or on-ground wood tanks. Typical capacity of storage tanks is in the range of 0.5 mgd to 2 mgd.

D.8.5 Pumping Plants (PP)

Pumping plants are usually composed of a building, one or more pumps, electrical equipment, and in some cases, backup power systems. Pumping plants are classified as either small PP with less than 10 mgd capacity or medium/large PP with more than 10 mgd capacity. Pumping plants are also classified with respect to whether or not the subcomponents (equipment and backup power) are anchored.

D.8.6 Terminal Reservoirs

Terminal reservoirs are typically lakes (man made or natural) and are usually located nearby and upstream of the water treatment plant. Vulnerability of terminal reservoirs and associated dams is marginally assessed in the loss estimation methodology. Therefore, even though reservoirs are an essential part of a potable water system, it is assumed in the analysis of water systems that the amount of water flowing into water treatment plants from reservoirs right after an earthquake is essentially the same as before the earthquake.

D.9 Waste Water System

A waste water system typically consists of collection sewers, interceptors, waste water treatment plants and lift stations as listed below. In this section, a brief description of each of these components is given.

- Buried Pipelines
- Waste Water Treatment Plants
- Lift Stations

D.9.1 Collection Sewers

Collection sewers are generally closed conduits that carry sewage normally with a partial flow. Collection sewers could be sanitary sewers, storm sewers, or combined sewers. Pipe materials that are used for potable water transportation may also be used for wastewater collection. The most commonly used sewer material is clay pipe manufactured with integral bell and spigot ends. These pipes range in size from 4 to 42 inch in diameter. Concrete pipes are mostly used for storm drains and for sanitary sewers carrying noncorrosive sewage (i.e. with organic materials). For the smaller diameter range, plastic pipes are also used.

D.9.2 Interceptors

Interceptors are large diameter sewer mains. They are usually located at the lowest elevation areas. Pipe materials that are used for interceptor sewers are similar to those used for collection sewers.

D.9.3 Lift Stations (LS)

Lift stations are important parts of the waste water system. Lift stations serve to raise sewage over topographical rises. If the lift station is out of service for more than a short time, untreated sewage will either spill out near the lift station, or back up into the collection sewer system.

In this study, lift stations are classified as either small LS (capacity less than 10 mgd) or medium/large LS (capacity greater than 10 mgd). Cases of lift stations with anchored versus unanchored subcomponents are also investigated.

D.9.4 Waste Water Treatment Plants (WWTP)

Three sizes of waste water treatment plants are considered: small (capacity less than 50 mgd), medium (capacity between 50 and 200 mgd), and large (capacity greater than 200 mgd). A WWTP has the same processes existing in a WTP with the addition of secondary treatment subcomponents.

D.10 Oil System

An oil system typically consists of refineries, pumping plants, tank farms, and pipelines as listed below. In this section, a brief description of each of these components is given.

- Pipelines
- Refineries
- Pumping Plants
- Tank Farms

D.10.1 Refineries (RF)

Refineries are an important part of an oil system. They are used for processing crude oil before it can be used. Two sizes of refineries are considered: small, and medium/large.

- ***Small refineries*** have a capacity of less than 100,000 barrels per day. These usually consist of steel tanks on grade, stacks, other electrical and mechanical equipment, and elevated pipes. Stacks are essentially tall cylindrical chimneys.
- ***Medium/Large refineries*** have a capacity of more than 100,000 barrels per day. These also consist of steel tanks on grade, stacks, other electrical and mechanical equipment, and elevated pipes.

D.10.2 Oil Pipelines

Oil pipelines are used for the transportation of oil over long distances. About seventy-five percent of the crude oil is transported throughout the United States by pipelines. A large segment of industry and millions of people could be severely affected by disruption of crude oil supplies. Rupture of crude oil pipelines could lead to a large scale environmental disaster due to pollution of land and rivers. Pipelines are typically made of mild steel with submerged arc welded joints, although older gas welded steel pipe may be present in some systems.

D.10.3 Pumping Plants (PP)

Pumping plants serve to maintain the flow of oil in cross country pipelines. Pumping plants usually use two or more pumps. Pumps can be of either centrifugal or reciprocating type. However, no differentiation is made between these two types of pumps in the analysis of oil systems. There are pumping plants with anchored as well as unanchored subcomponents.

D.10.4 Tank Farms (TF)

Tank farms are facilities which store fuel products. They include tanks, pipes and electric components. There are tank farms with anchored as well as unanchored subcomponents.

D.11 Natural Gas System

A natural gas system typically consists of compressor stations and pipelines as listed below. In this section, a brief description of each of these components is given.

- Buried Pipelines
- Compressor Stations

D.11.1 Compressor Stations

Compressor stations serve to maintain the flow of gas in cross country pipelines. Compressor stations consist of either centrifugal or reciprocating compressors. However, no differentiation is made between these two types of compressors in the analysis of natural gas systems. Cases of compressor stations with anchored versus unanchored subcomponents are also investigated.

D.11.2 Natural Gas Pipelines

Pipelines are typically made of mild steel with submerged arc welded joints, although older lines may have gas welded joints. These are used for the transportation of natural gas over long distances. Many industries and millions of people could be severely affected should disruption of natural gas supplies occur.

D.12 Electric Power System

The only components of an electric power system considered in the loss estimation methodology are substations, distribution circuits, and generation plantsm as listed below. In this section a brief description of each of these components is presented.

- Transmission Substations
- Distribution Circuits
- Generation Plants

D.12.1 Substations

An electric substation is a facility that serves as a source of energy supply for the local distribution area in which it is located, and has the following main functions:

- \- Change or switch voltage from one level to another.
- \- Provide points where safety devices such as disconnect switches, circuit breakers, and other equipment can be installed.
- \- Regulate voltage to compensate for system voltage changes.
- \- Eliminate lightning and switching surges from the system.
- \- Convert AC to DC and DC to AC, as needed.
- \- Change frequency, as needed.

Substations can be entirely enclosed in buildings where all the equipment is assembled into one metal clad unit. Other substations have step-down transformers, high voltage switches, oil circuit breakers, and lightning arrestors located outside the substation building. In the current loss estimation methodology, only transmission (138 kV to 765 kV or higher) and subtransmission (34.5 kV to 161 kV) substations are considered. Substations are also classified based on whether they have anchored or unanchored subcomponents. The substations are classified as:

- High Voltage: he line voltage at these substations is 350 kV or more. These are referred to as 500 kV substations.
- Medium Voltage: The line voltage at these substations is between 150 kV and 350 kV. These are referred to as 230 kV substations.
- Low Voltage: The line voltage at these substations is between 34.5 kV and 150 kV. These are referred to as 115 kV substations.

D.12.2 Distribution Circuits

The distribution system is divided into a number of circuits. A distribution circuit includes poles, wires, in-line equipment and utility-owned equipment at customer sites. A distribution circuit also includes above ground and underground conductors. Distribution circuits either consist of seismically designed components or standard components.

D.12.3 Generation Plants

Power generation plants are facilities where the coal, oil, natural gas, or atom are transformed into electrical energy. These plants produce alternating current (AC) and may be any of the following types:

- \- Hydroelectric
- \- Steam turbine (fossil fired or nuclear)
- \- Combustion turbine
- \- Geothermal
- \- Solar
- \- Wind
- \- Compressed air

Generation plant subcomponents include diesel generators, turbines, racks and panels, boilers and pressure vessels, and the building in which these are housed. The size of the generation plant is determined from the number of Megawatts of electric power that the plant can produce under normal operations. Small generation plants have a generation capacity of less than 200 Megawatts. Medium/Large generation plants have a capacity greater than 200 Megawatts. Fragility curves for generation plants with anchored versus unanchored subcomponents are presented.

D.13 Communication System

Only central offices are considered for the loss estimation of the communication systems as listed below. A central office consists of a building, central switching equipment (i.e., digital switches, anchored or unanchored), and back-up power supply (i.e. diesel generators or battery generators, anchored or unanchored) that may be needed to supply the requisite power to the center in case of loss of off-site power.

- Central Offices

Appendix E. Summary of Inventory Databases (Earthquake Module)

General Building Stock

Occupancy Square Footage

Building Type- Occupancy

Essential Facilities

Medical Care Facilities

Emergency Operation Centers

Schools

High Potential Loss Facilities

Dams

Nuclear Power Facilities

Military Installations

Transportation System

Highway Segments

Highway Bridges

Highway Tunnels

Railway Track Segments

Railway Bridges

Railway Tunnels

Railway Facilities

Light Rail Track Segments

Light Rail Bridges

Light Rail Tunnels

Light Rail Facilities

Bus Facilities

Ports and Harbors Facilities

Ferry Facilities

Airports Facilities

Airports Runways

Utility System

Potable Water Pipeline Segments

Potable Water Facilities

Potable Water Distribution Lines

Waste Water Pipeline Segments

Waste Water Facilities

Waste Water Distribution Lines

Oil Pipelines Segments

Oil Systems Facilities

Natural Gas Pipelines Segments

Natural Gas Facilities

Natural Gas Distribution Lines
Electric Power Facilities
Electric Power Distribution Lines
Communication Facilities
Communication Distribution Cables

Hazardous Materials Facilities

Population Inventory

Appendix G. Questionnaire for Assessing Characteristics of Regional Building Stock

Workshop to Evaluate the Design and Construction of Local Region

G.1 Part 1: General Information

Name: ____ **Date**: _______________

Region or regions you represent: __________________________________

Type of Experience in Region **Number of Years Experience**
(e.g. designer, inspector, planner, plan checker contractor, etc.)

_____________________________________ ___________

_____________________________________ ___________

_____________________________________ ___________

_____________________________________ ___________

G.2 Part 2: Specific Design and Construction Practices for the Region

Review the Model Building Types in the Appendix. Do these Model Building Types completely represent the construction types in your region? That is, describe any building types which you cannot map into the Model Building Types.

____
____
____

Which building code is currently in effect in your region? __________________________

Are there building types that are unique to your region or that typify your region (e.g. brownstone, Victorian, adobe block)? Please give a description of these building types and what makes them unique.

____
____

Is there a year that you can identify for your region when Unreinforced Masonry (URM) ceased to be built?

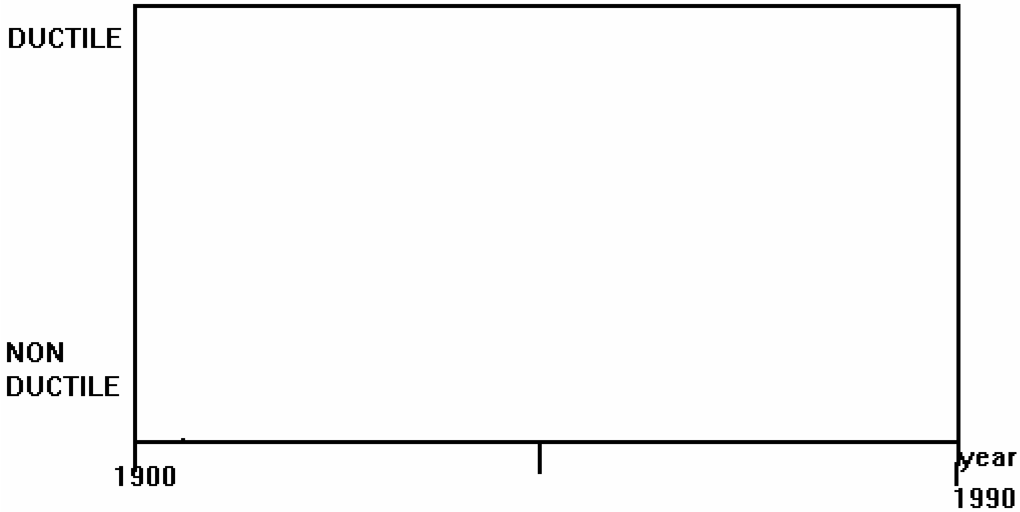
Is there a year that you can identify in which Reinforced Masonry (RM) began to be built?

Represent the distribution of construction of RM and URM on the graph below.

When did you start to build Steel Moment Resistant Frames in your region?

When did you start to build ductile concrete in your region?

What is the distribution of ductile versus non-ductile concrete frames for your region:



When did you stop building steel frames with URM infill walls?

____

____

For high rise structures (8+ stories) in your region can you provide a distribution of structural type over time (steel, concrete, masonry).

For low rise large wholesale/light industrial structures in your region can you provide a distribution of structural type over time (steel, reinforced concrete, masonry, tilt-up, wood).

Reviewing the model building types as described Appendix A, can you identify important "benchmark" years? These would be years when significant code changes occurred in your region so that the performance of the structures, when subjected to natural hazards such as wind earthquake and flood, improved? Some examples might be required bolting of the structure to the foundation, required use of hurricane clips, or improved connection of tilt-up walls to roof diaphragms.

Year	Improvement	Code Requiring Improvement
______	________________________________	________________________________
______	________________________________	________________________________
______	________________________________	________________________________
______	________________________________	________________________________
______	________________________________	________________________________
______	________________________________	________________________________
______	________________________________	________________________________

Can you identify when significant changes in building practices occurred in your region that effect the calculation of vulnerability of buildings to natural hazards such as wind, earthquake and flood? Some examples might be introduction of a new building type such as tilt-ups, discontinued use of a particular building material, discontinued use of cripple walls, significant housing development during a particular era.

____

____

____

____

____

____

The current NIBS/FEMA methodology divides structures into three groups (pre-1950, 1950-1970, post-1970). Based upon your answers to the previous questions does this age breakdown make sense for your region? If not can you suggest something that better reflects the design and construction practices of your region? It can have more than three age groupings.

____

____

____

____

Is there any other information particular to your region that you feel is important assessing building vulnerability?

____

____

____

____

G.3 Part3: Occupancy to General Building Type Relationships for the Local Region

For several states in your region as shown below, insurance data suggests that the mix of building types in terms of percentage of total square footage is:

State ____________:

	Wood Frame	Masonry	Rfd. Concrete	Steel	Light Metal	Mobile Home
Residential						
Commercial						

State ____________:

	Wood Frame	Masonry	Rfd. Concrete	Steel	Light Metal	Mobile Home
Residential						
Commercial						

State ____________:

	Wood Frame	Masonry	Rfd. Concrete	Steel	Light Metal	Mobile Home
Residential						
Commercial						

State ____________:

	Wood Frame	Masonry	Rfd. Concrete	Steel	Light Metal	Mobile Home
Residential						
Commercial						

Based upon your experience, do these relationships look reasonable? If not which numbers are you questioning?

____

____

____

Use the table below to enter an improved distribution of building types for each occupancy.

Improved General Occupancy to Building Type Relationship for The Local Region

	Wood Frame	Masonry	Reinforced Concrete	Steel	Light Metal	Mobile Home
Residential						
Commercial						

Occupancy to model building type relationships have been developed for several counties based on the analysis of county assessor's records. The occupancy to model building type relationships are based upon percentage of total square footage for each occupancy. You'll note for certain occupancies such as government and non-profit agencies, assessor's files do not provide adequate information to establish a relationship. The occupancy to model building type relationships are found in the Appendix. Please review the appendix and identify which county best reflects your region.

County ____

Based upon your experience, what distributions do you think need revision?

Occupancy **Problem**

______ ____

______ ____

______ ____

______ ____

______ ____

Please enter your improved estimates of occupancy to model building type relationships in the tables below.

URBAN

Label	Class	Wood Frame	Steel	Concrete	Masonry	Mobile Home
RES1	Single Family Dwelling					
RES2	Mobile Home					
RES3	Multi Family Dwelling					
RES4	Temporary Lodging					
RES5	Institutional Dormitory					
RES6	Nursing Home					
COM1	Retail Trade					
COM2	Wholesale Trade					
COM3	Personal and Repair Services					
COM4	Professional/Technical Srv					
COM5	Banks					
COM6	Hospital					
COM7	Medical Office/Clinic					
COM8	Entertainment & Recreation					
COM9	Theaters					
COM10	Parking					
IND1	Heavy					
IND2	Light					
IND3	Food/Drugs/Chemicals					
IND4	Metals/Minerals Processing					
IND5	High Technology					
IND6	Construction					
AGR	Agriculture					
REL	Church/Non Profit					
GOV1	General Services					
GOV2	Emergency Services					
ED1	Schools/Libraries					
ED2	Colleges/ Universities					

SUBURBAN

Label	Class	Wood Frame	Steel	Concrete	Masonry	Mobile Home
RES1	Single Family Dwelling					
RES2	Mobile Home					
RES3	Multi Family Dwelling					
RES4	Temporary Lodging					
RES5	Institutional Dormitory					
RES6	Nursing Home					
COM1	Retail Trade					
COM2	Wholesale Trade					
COM3	Personal and Repair Services					
COM4	Professional/Technical Srv					
COM5	Banks					
COM6	Hospital					
COM7	Medical Office/Clinic					
COM8	Entertainment & Recreation					
COM9	Theaters					
COM10	Parking					
IND1	Heavy					
IND2	Light					
IND3	Food/Drugs/Chemicals					
IND4	Metals/Minerals Processing					
IND5	High Technology					
IND6	Construction					
AGR	Agriculture					
REL	Church/Non Profit					
GOV1	General Services					
GOV2	Emergency Services					
ED1	Schools/Libraries					
ED2	Colleges/ Universities					

G.4 Part 4: General to Specific Occupancy Relationship for the Local Region

Based upon your experience, how would steel frames in your region be distributed among the five types listed below?

Steel Frame Distribution by Percentage of Total Square Footage

	Steel Moment Frame	Steel Braced Frame	Steel Light Frame	Steel Frame w/ Cast-in-Place Concrete Shear Walls	Steel Frame w/ Unreinforced Masonry Infill Walls	Other (Specify)
Low rise						
Mid rise						
High rise						

Confidence: ____

Is there either an age or occupancy factor that would cause you to skew your answers. For example a particular occupancy uses a unique structural type or does not use one of the types listed above. If so state your skewed answer in the table below

Factor Affecting Distribution ___________________________________

Steel Frame Distribution by Percentage of Total Square Footage

	Steel Moment Frame	Steel Braced Frame	Steel Light Frame	Steel Frame w/ CIP Concrete Shear Walls	Steel Frame w/ URM Infill Walls	Other
Low rise						
Mid rise						
High rise						

Factor Affecting Distribution ___________________________________

Steel Frame Distribution by Percentage of Total Square Footage

	Steel Moment Frame	Steel Braced Frame	Steel Light Frame	Steel Frame w/ CIP Concrete Shear Walls	Steel Frame w/ URM Infill Walls	Other
Low rise						
Mid rise						
High rise						

Factor Affecting Distribution ___________________________________

Steel Frame Distribution by Percentage of Total Square Footage

	Steel Moment Frame	Steel Braced Frame	Steel Light Frame	Steel Frame w/ CIP Concrete Shear Walls	Steel Frame w/ URM Infill Walls	Other
Low rise						
Mid rise						
High rise						

Based upon your experience, how would concrete structures in your region be distributed among the five types listed below?

Concrete Distribution by Percentage of Total Square Footage

	Concrete Moment Frames	Concrete Shear Walls	Concrete Frames w/ URM Infill Walls	Precast-Concrete Tilt-Up Walls	Precast Concrete Frames w/ Concrete Shear Walls	Other (Specify)
Low rise						
Mid rise						
High rise						

Confidence: ____

Is there either an age or occupancy factor that would cause you to skew your answers. For example a particular occupancy uses a unique structural type or does not use one of the types listed above. If so state your skewed answer in the table below

Factor Affecting Distribution ___________________________________

Concrete Distribution by Percentage of Total Square Footage

	Concrete Moment Frames	**Concrete Shear Walls**	**Concrete Frames URM Infill Walls**	**Precast-Concrete Tilt-Up Walls**	**Precast Concrete Frames w/ Concrete Shear Walls**	**Other**
Low rise						
Mid rise						
High rise						

Factor Affecting Distribution ___________________________________

Concrete Distribution by Percentage of Total Square Footage

	Concrete Moment Frames	**Concrete Shear Walls**	**Concrete Frames URM Infill Walls**	**Precast-Concrete Tilt-Up Walls**	**Precast Concrete Frames w/ Concrete Shear Walls**	**Other**
Low rise						
Mid rise						
High rise						

Factor Affecting Distribution ___________________________________

Concrete Distribution by Percentage of Total Square Footage

	Concrete Moment	**Concrete Shear**	**Concrete Frames**	**Precast-Concrete**	**Precast Concrete**	**Other**

	Frames	Walls	URM Infill Walls	Tilt-Up Walls	Frames w/ Concrete Shear Walls	
Low rise						
Mid rise						
High rise						

Based upon your experience, how would masonry structures in your region be distributed among the three types listed below?

Masonry Distribution by Percentage of Total Square Footage

	Reinforced Masonry Walls w/ Wood/ Metal Deck Diaphragms	Reinforced Masonry Walls w/ PC Diaphragms	Unreinforced Masonry (URM) Bearing Walls	Other
Low rise				
Mid rise				
High rise				

Confidence: ___________________________________

Is there either an age or occupancy factor that would cause you to skew your answers. For example a particular occupancy uses a unique structural type or does not use one of the types listed above. If so state your skewed answer in the table below

Factor Affecting Distribution ___________________________________

Masonry Distribution by Percentage of Total Square Footage

	Reinforced Masonry Walls w/ Wood/ Metal Deck Diaphragms	Reinforced Masonry Walls w/ PC Diaphragms	Unreinforced Masonry (URM) Bearing Walls	Other
Low rise				
Mid rise				
High rise				

Factor Affecting Distribution ___________________________________

Masonry Distribution by Percentage of Total Square Footage

	Reinforced Masonry Walls w/ Wood/ Metal Deck Diaphragms	Reinforced Masonry Walls w/ PC Diaphragms	Unreinforced Masonry (URM) Bearing Walls	Other
Low rise				
Mid rise				
High rise				

Factor Affecting Distribution ___________________________________

Masonry Distribution by Percentage of Total Square Footage

	Reinforced Masonry Walls w/ Wood/ Metal Deck Diaphragms	Reinforced Masonry Walls w/ PC Diaphragms	Unreinforced Masonry (URM) Bearing Walls	Other
Low rise				
Mid rise				
High rise				

Appendix H. Hazardous Materials Classification and Permit Amounts

The most widely used detailed classification scheme is the one that has been developed by the National Fire Protection Association, and is presented in the 1991 Uniform Fire Code, among other documents. This classification scheme is shown in Table H1. Sixty material types have been defined (HM01 to HM60). The hazards posed by the various materials are divided into two major categories: Physical Hazards and Health Hazards. Depending upon the exact nature of the hazard, these two major categories are divided into subcategories. Examples are poison, carcinogen, mildly toxic, moderately toxic or skin irritant. These subcategories of hazards, with their definitions, and examples of materials that fall within each category, are contained in Appendix 11A and 11B of the Technical Manual. A more detailed description of these categories, with more extensive examples can be found in Appendix VI-A of the 1991 Uniform Fire Code.

Table H1 also contains minimum quantities of the materials that must be on site to require permitting according to the Uniform Fire Code. It should be noted that the minimum permit quantities may vary depending upon whether the chemical is stored inside or outside of a building. For facilities that have hazardous materials, but in quantities less than those listed in Table H1, it is anticipated that releases of these small quantities will not put significant immediate demands on health and emergency services, thus you may wish to exclude them from the database.

Table H1 Classification of Hazardous Materials and Permit Amounts

Label	Material Type	Permit Amount		Hazard Type Remarks
		Inside Building	Outside Building	
HM01	Carcinogens	10 lbs	10 lbs	Health
HM02	Cellulose nitrate	25 lbs	25 lbs	Physical
HM03	Combustible fibers	100 cubic ft	100 cubic ft	Physical
	Combustible liquids			Physical
HM04	Class I	5 gallons	10 gallons	
HM05	Class II	25 gallons	60 gallons	
HM06	Class III-A	25 gallons	60 gallons	
HM07	Corrosive gases	Any amount	Any amount	Health [1]
HM08	Corrosive liquids	55 gallons	55 gallons	Physical; Health
	Cryogens			
HM09	Corrosive	1 gallon	1 gallon	Health
HM10	Flammable	1 gallon	60 gallons	Physical
HM11	Highly toxic	1 gallon	1 gallon	Health
HM12	Nonflammable	60 gallons	500 gallons	Physical
HM13	Oxidizer (including oxygen)	50 gallons	50 gallons	Physical
HM14	Highly toxic gases	Any amount	Any amount	Health; [1]
HM15	Highly toxic liquids & solids	Any amount	Any amount	Health
HM16	Inert	6,000 cubic ft	6,000 cubic ft	Physical; [1]
HM17	Irritant liquids	55 gallons	55 gallons	Health
HM18	Irritant solids	500 lbs	500 lbs	Health
HM19	Liquefied petroleum gases	> 125 gallons	> 125 gallons	Physical
HM20	Magnesium	10 lbs	10 lbs	Physical
HM21	Nitrate film	(Unclear)	(Unclear)	Health
HM22	Oxidizing gases (including oxygen)	500 cubic feet	500 cubic feet	Physical [1]
	Oxidizing liquids			Physical
HM23	Class 4	Any amount	Any amount	
HM24	Class 3	1 gallon	1 gallon	
HM25	Class 2	10 gallons	10 gallons	
HM26	Class 1	55 gallons	55 gallons	
	Oxidizing solids			Physical
HM27	Class 4	Any amount	Any amount	
HM28	Class 3	10 lbs	10 lbs	
HM29	Class 2	100 lbs	100 lbs	
HM30	Class 1	500 lbs	500 lbs	
	Organic peroxide liquids and solids			Physical
HM31	Class I	Any amount	Any amount	
HM32	Class II	Any amount	Any amount	
HM33	Class III	10 lbs	10 lbs	
HM34	Class IV	20 lbs	20 lbs	
	Other health hazards			Health
HM35	Liquids	55 gallons	55 gallons	
HM36	Solids	500 lbs	500 lbs	
HM37	Pyrophoric gases	Any amount	Any amount	Physical [1]
HM38	Pyrophoric liquids	Any amount	Any amount	Physical
HM39	Pyrophoric solids	Any amount	Any amount	Physical
HM40	Radioactive materials	1 m Curie in unsealed source	1 m Curie in sealed source	Health [1]
HM41	Sensitizer, liquids	55 gallons	55 gallons	Health
HM42	Sensitizer, solids	500 lbs	500 lbs	Health
HM43	Toxic gases	Any amount	Any amount	Health [1]

Table H1 Classification of Hazardous Materials and Permit Amounts (Cont.)

Label	Material Type	Permit Amount		Hazard Type Remarks
		Inside Building	Outside Building	
HM44	Toxic liquids	50 gallons	50 gallons	Health
HM45	Toxic solids	500 lbs	500 lbs	Health
HM46	Unstable gases (reactive)	Any amount	Any amount	Physical[1]
	Unstable liquids (reactive)			Physical
HM47	Class 4	Any amount	Any amount	
HM48	Class 3	Any amount	Any amount	
HM49	Class 2	5 gallons	5 gallons	
HM50	Class 1	10 gallons	10 gallons	
	Unstable solids (reactive)			Physical
HM51	Class 4	Any amount	Any amount	
HM52	Class 3	Any amount	Any amount	
HM53	Class 2	50 lbs	50 lbs	
HM54	Class 1	100 lbs	100 lbs	
	Water-reactive liquids			Physical
HM55	Class 3	Any amount	Any amount	
HM56	Class 2	5 gallons	5 gallons	
HM57	Class 1	10 gallons	10 gallons	
	Water-reactive solids			Physical
HM58	Class 3	Any amount	Any amount	
HM59	Class 2	50 pounds	50 pounds	
HM60	Class 1	100 pounds	100 pounds	

[1] Includes compressed gases

Appendix I. Glossary of Terms

Attenuation Relationship - A relationship that describes how ground motions (acceleration and velocities) decrease as a function of distance from the earthquake source.

Building Period - Buildings tend to shake at different speeds. The period tells us how long it takes for a building to shake back and forth one time. Tall buildings have longer periods on the order of 1 to 4 seconds. Short buildings move back and forth very rapidly and have periods on the order of 0.1 to 0.4 seconds. The building frequency is also a measure of the speed at which a building shakes.

Building Frequency - The building frequency is the reciprocal of the period, that is it is a measure of how many times the building shakes back and forth every second. If a building has a period of 2 seconds, its frequency is 0.5 Hz (cycles per second).

CAS - Chemical Abstracts Service registry number. This is a numeric designation assigned by the American Chemical Society's Chemical Abstracts Service that uniquely identifies a specific chemical compound.

Damage Ratio - Cost of repair as a fraction of replacement cost.

Direct Economic Loss - In this methodology the costs of structural and non-structural repair, damage to building contents, loss of building inventory, relocation expenses, lost wages and lost income.

GIS (geographic information system) - Software tool for displaying, analyzing and manipulating spatially related data. Data is stored in layers which can be overlaid and combined to map data.

HAZUS - A software package developed to estimate losses estimates due to natural hazards for the United States. The name is derived from *Hazards U.S.*

Indirect Economic Loss - In this methodology the long-term regional economic effects.

Liquefaction - A phenomenon where due to shaking, soil losses its strength and essentially acts like a liquid.

MMI (Modified Mercalli Intensity) - A system for measuring the damage that occurs in an earthquake. The scale is measured from I to XII. A I is not felt by people and a XII causes essentially total damage to the built environment.

NEHRP -National Earthquake Hazards Reduction Program

PESH (potential earth science hazards) - In this methodology PESH is that group of physical attributes and consequences that describe the potential damageability of the earthquake. These include the ground motion (PGA, PGV, spectral acceleration, spectral velocity), ground failure (liquefaction, landslide and surface fault rupture), tsunami and seiche.

PGA - Peak Ground Acceleration. The largest acceleration that can be expected at a particular site due to an earthquake.

PGD - Permanent Ground Deformation - This is a quantification of the ground failure that occurs as a result of liquefaction, landslides and surface fault rupture. It is measured in inches and describes how far the surface of the ground moves.

PGV - Peak Ground Velocity

Seiche - Waves in a lake or reservoir that are induced because of ground shaking.

Shear Waves - Shear waves (S waves) are one of the many types of waves that are generated by an earthquake. Each type of wave shakes the ground differently (some fast, some slow, some up and down, some sideways).

Shear Wave Velocity - Shear waves travel through different types of soils at different velocities (speeds). Shear wave travel more quickly through rock and hard soils and more slowly through soft soils. The shear wave velocity can then be used as a measure of the type of soil.

Spectral Acceleration - The acceleration of earthquake motion at a specified building period. See definition of spectral velocity

Spectral Velocity - The velocity of earthquake motion at a specified building period. Earthquake shaking is a complex mixture of movements at different frequencies. Some of the shaking is fast and some of it is slow. Different buildings respond to different types of shaking. Short buildings tend to respond to fast shaking and tall buildings respond to slower shaking. Thus if an earthquake has a lot of fast shaking we would expect it to excite low rise buildings. By breaking apart the earthquake shaking and looking at one part at a time, in terms of building period, we can see which buildings will experience higher levels of motion.

Thematic Map - A map that uses color, patterns and/or symbols to graphically represent characteristics of a set of data. Graphical representations include shaded ranges, shaded individual values, bar charts, pie charts, graduated symbols and dot density.

TIGER files- Topologically Integrated Geographic Encoding and Referencing system. This is a system developed by the U.S. Census Bureau that can be used for inventory development. Files contain roads, streets, railways, waterways and census boundaries. See Section 6.8.5.

Tsunami - Tsunami translates as “harbor wave.” These ocean waves can be caused by the direct effects of subduction earthquake and the secondary effects of earthquake triggered submarine landslides. Their heights can be greater than 10 meters.

Appendix J: GeoDatabase based Shake Maps

J.1 Introduction

J.1.1 Purpose

The goal of the document is to show how the USGS Shake Maps (based on shp files) could be converted into GeoDatabase based Shake Maps.

J.1.2 Scope

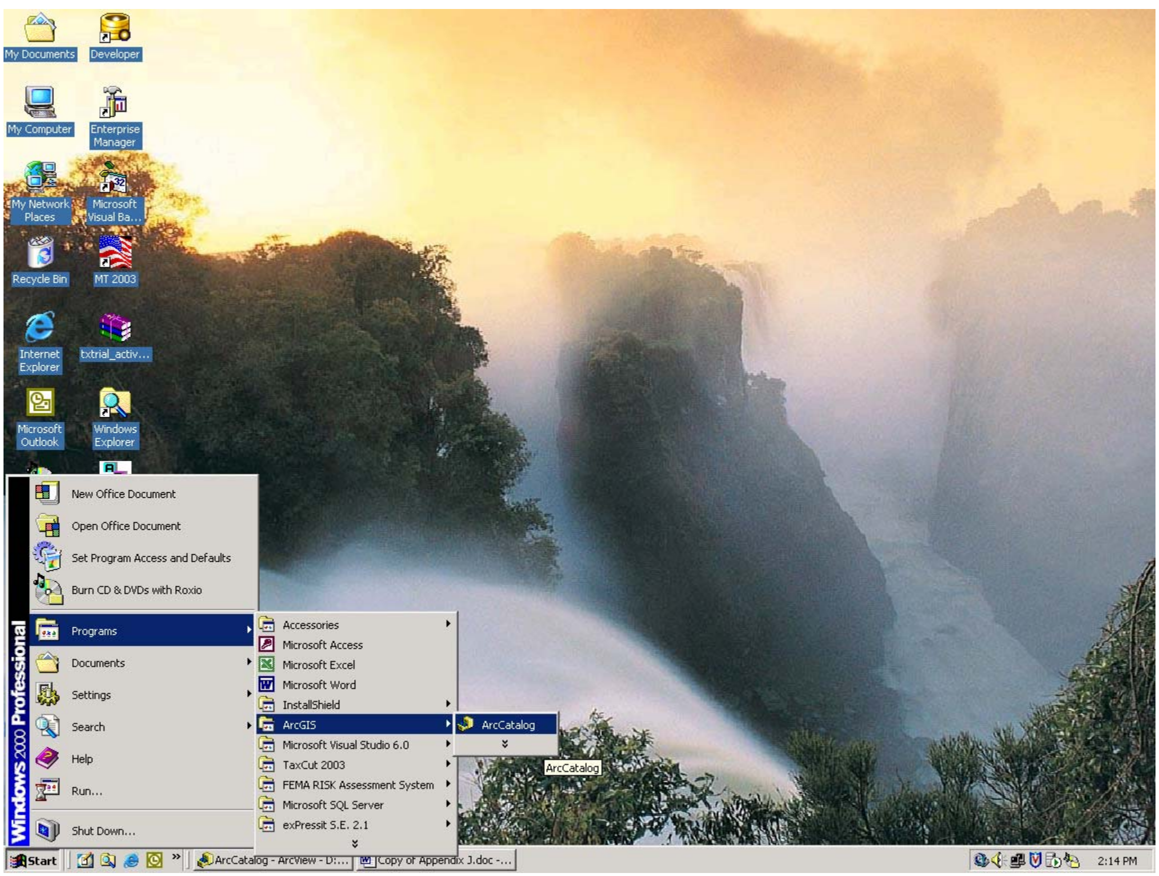
This document describes how SHP file based Shake Maps could be converted into GeoDatabase based Shake Maps in a step by step way. The focus is entirely on what is important to make the new GeoDatabases work with HAZUS-MH. This document should not be used as a resource for converting SHP files to GeoDatabases.

J.2 Prerequisites

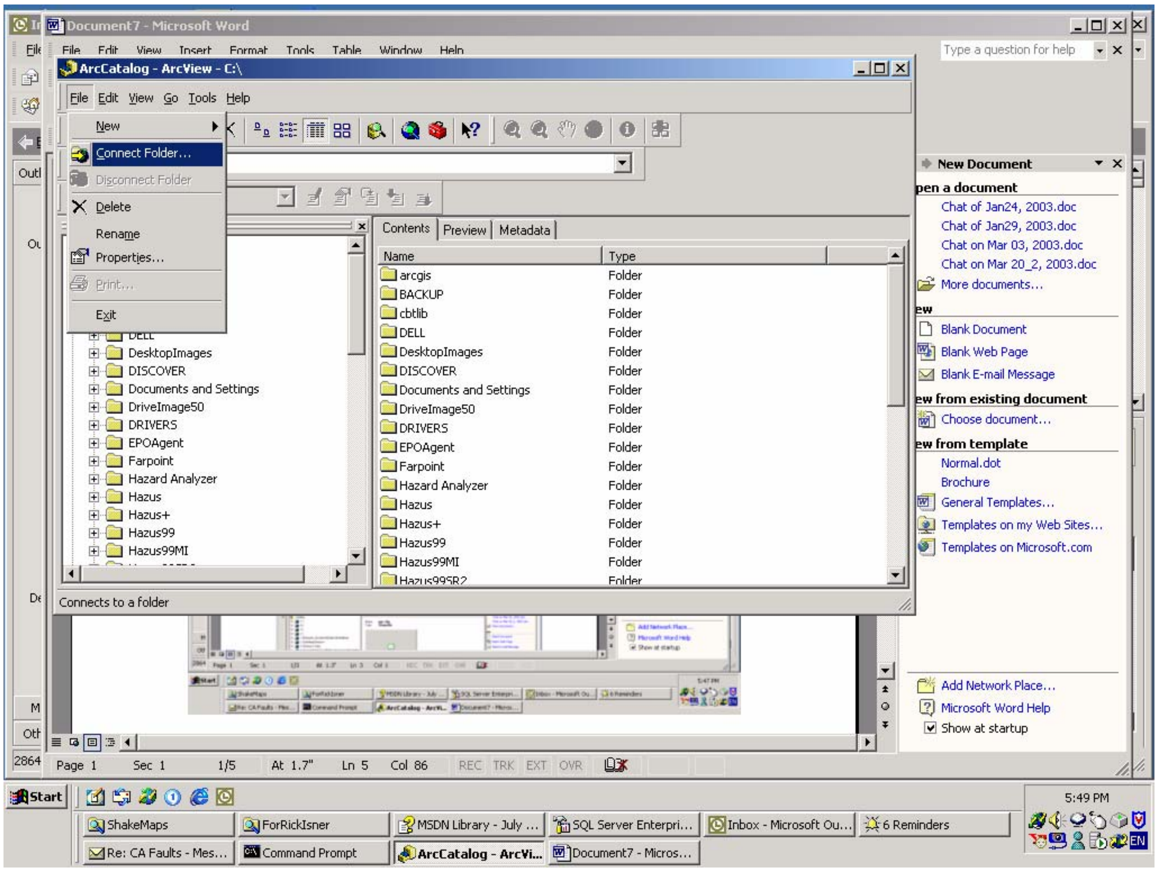
ArcGIS 9.0 (ArcMap and ArcCatalog) should be installed on the computer.

J.3 Creating GeoDatabase based Shake Maps

1) Launch ArcCatalog from the Start menu.

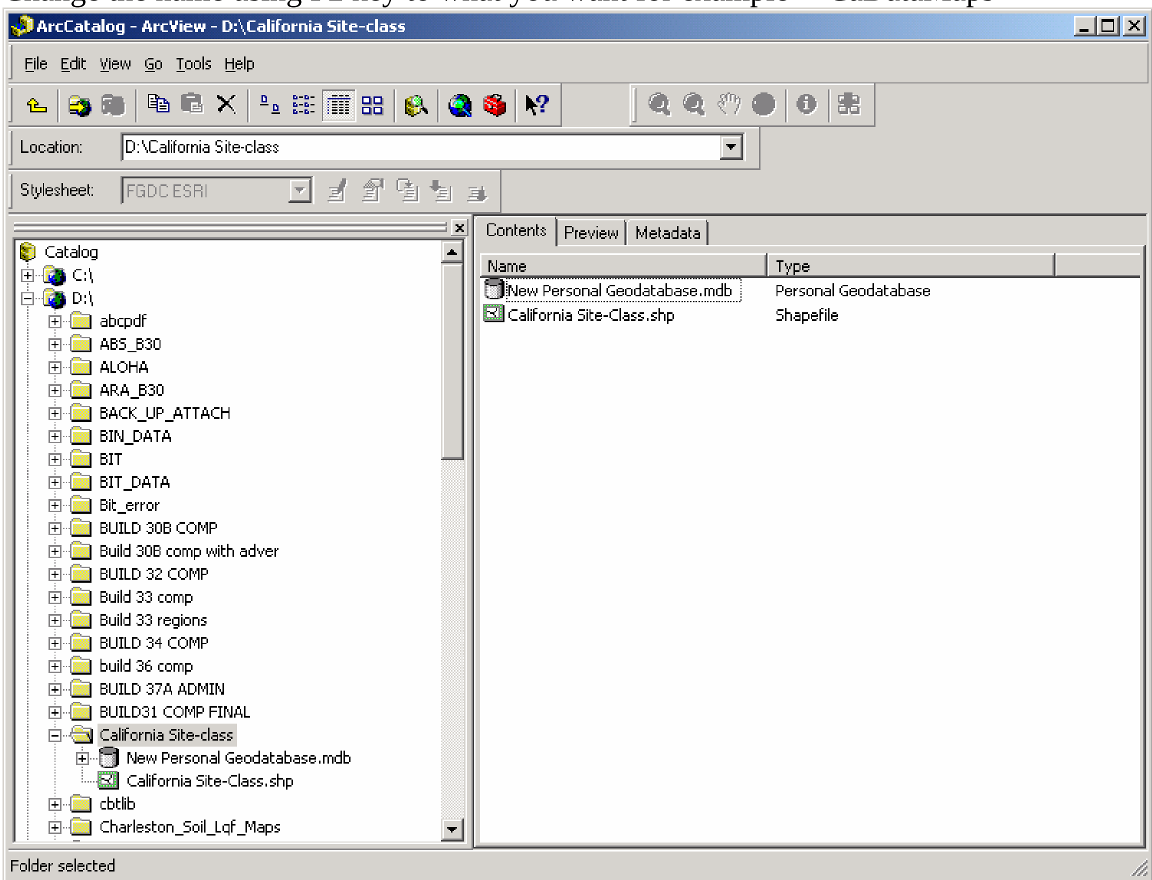


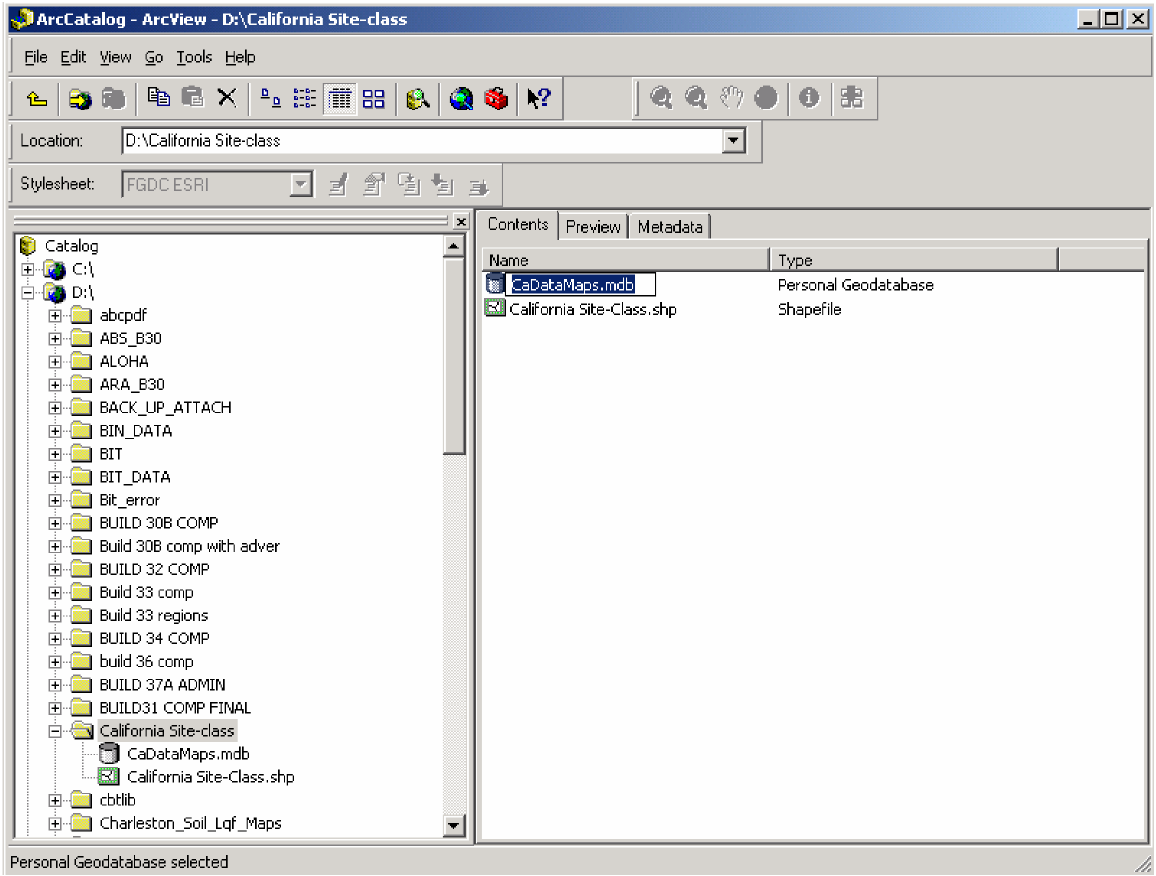
2) Click on the folder where the new Geo-Database is to be created. In case the folder is not available in ArcCatalog click on **File>Connect Folder** menu and select the folder where the Geo-Database is to be created. Once OK button is pressed on that dialog the folder will be visible in ArcCatalog



3) Select the Folder in TOC of the Arc catalog where the Geo-Database is to be created (the one added in the above step), Click on **File>New>Personal GeoDatabase** menu to create the new personal geodatabase.
By default the name appears as “New Personal Geodatabse”

Change the name using F2 key to what you want for example “CaDataMaps”

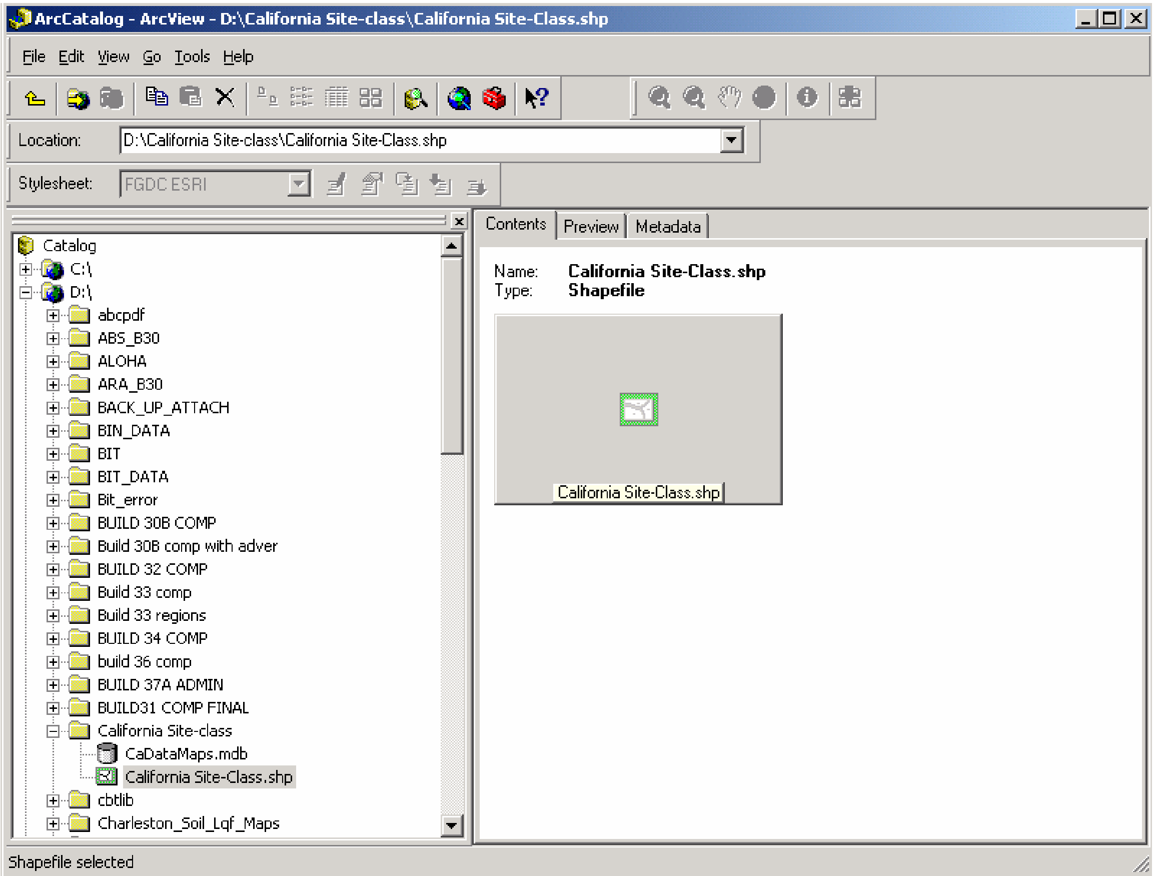




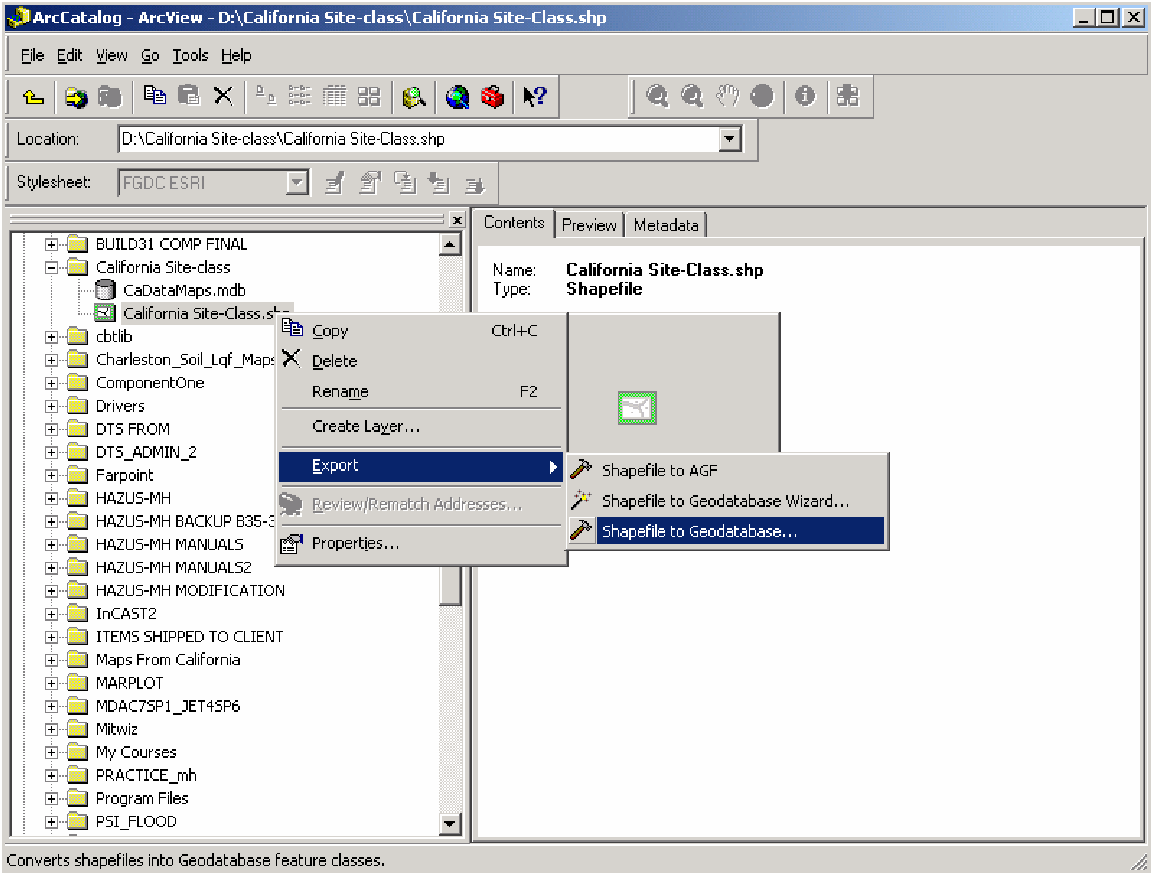
ArcCatalog - ArcView - D:\California Site-class
File Edit View Go Tools Help
Location: D:\California Site-class
Stylesheet: FGDC ESRI
Contents Preview Metadata
Name Type
CaDataMaps.mdb Personal Geodatabase
California Site-Class.shp Shapefile
Catalog
C:\
D:\
abcpdf
ABS_B30
ALOHA
ARA_B30
BACK_UP_ATTACH
BIN_DATA
BIT
BIT_DATA
Bit_error
BUILD 30B COMP
Build 30B comp with adver
BUILD 32 COMP
Build 33 comp
Build 33 regions
BUILD 34 COMP
build 36 comp
BUILD 37A ADMIN
BUILD31 COMP FINAL
California Site-class
CaDataMaps.mdb
California Site-Class.shp
cbtlib
Charleston_Soil_Lqf_Maps
Personal Geodatabase selected

4) Select the folder where the shake maps are located in ArcCatalog's TOC. In the folder is not available in the TOC click on **File>Connect Folder** menu and select the folder where the shake maps are located, press the OK button and the folder will be visible in ArcCatalog's TOC.

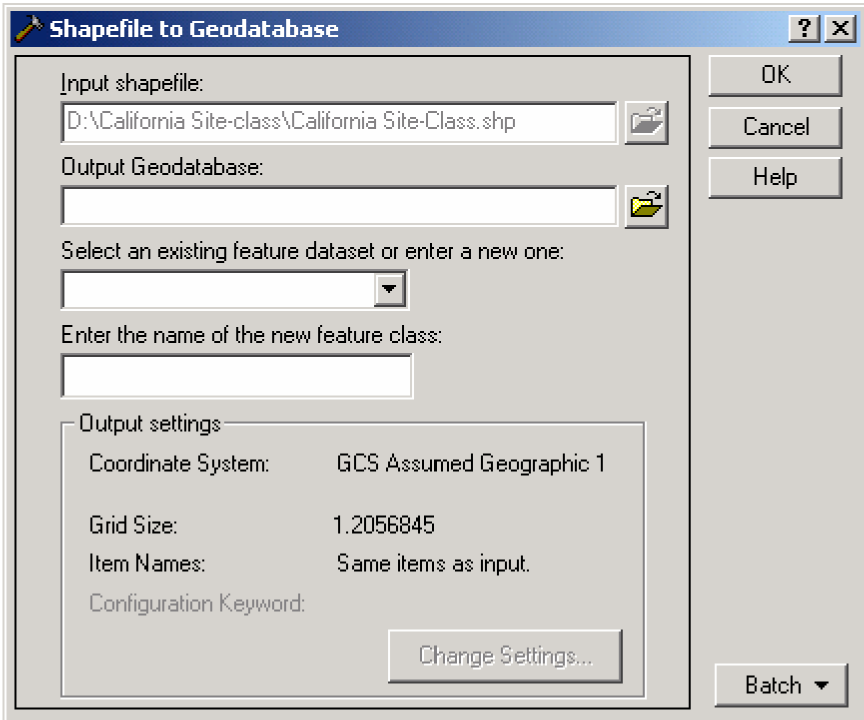
5) Select the Shape file which is to be exported under the connected folder in TOC as shown



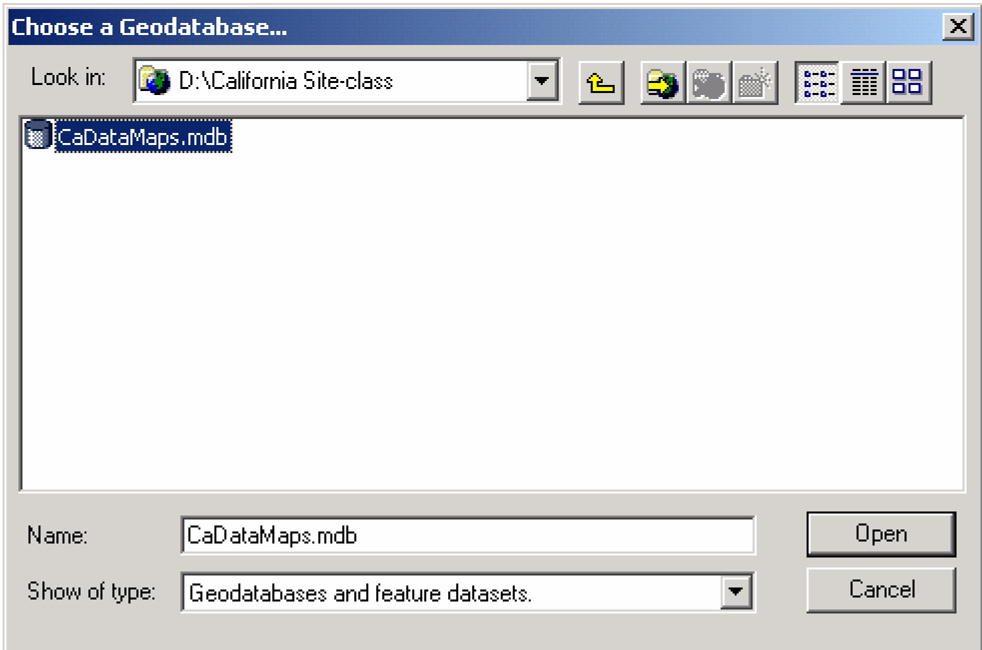
6) Right click and select third option under Export (shape file to geo database) as shown



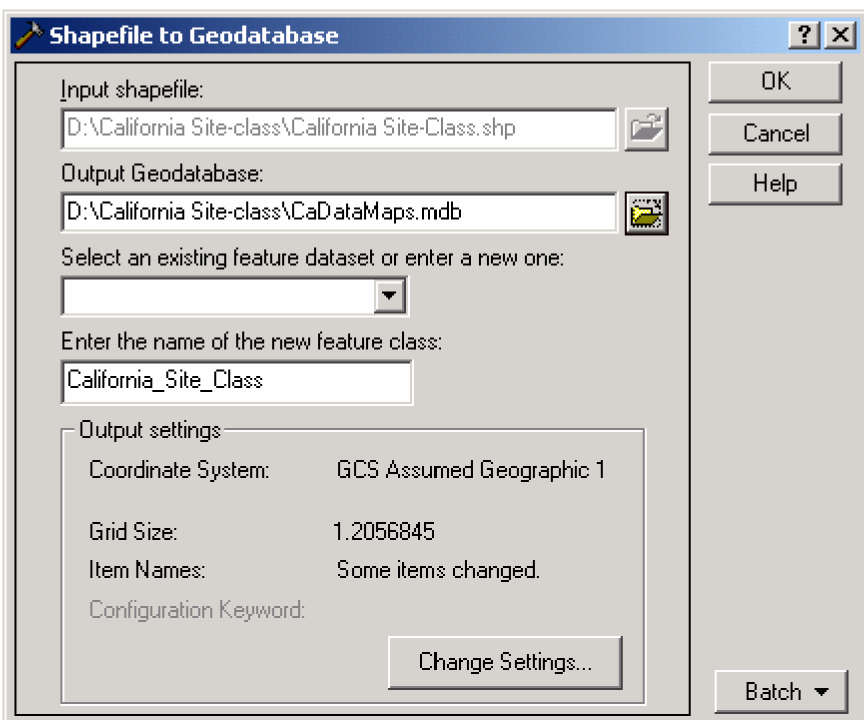
7) The Export option will show the following dialog



8) Click on the browse button for the Out put Geo data base and select the geo database created in step 3.

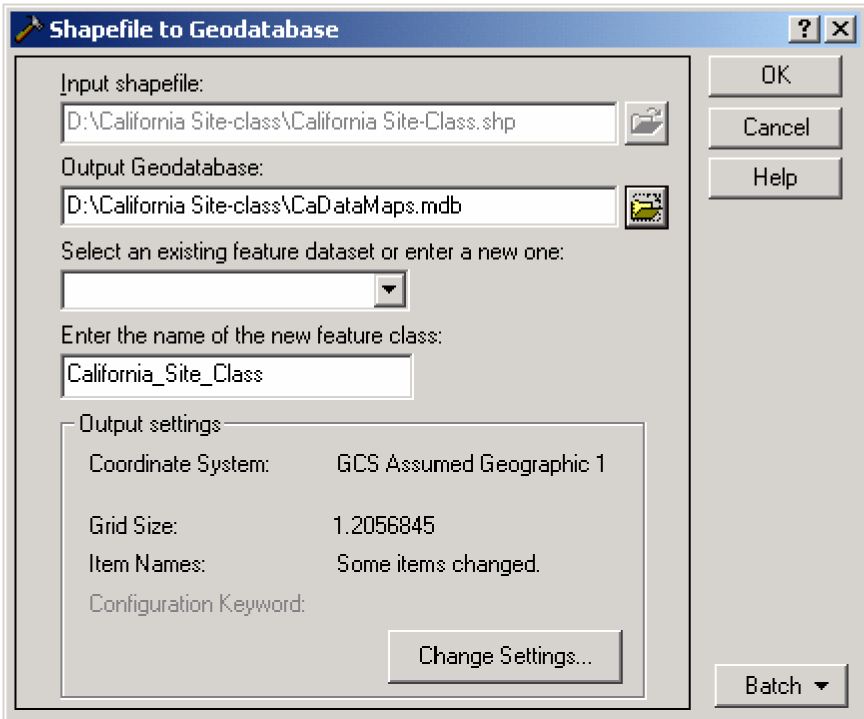


Clicking Open button will launch the following dialog:

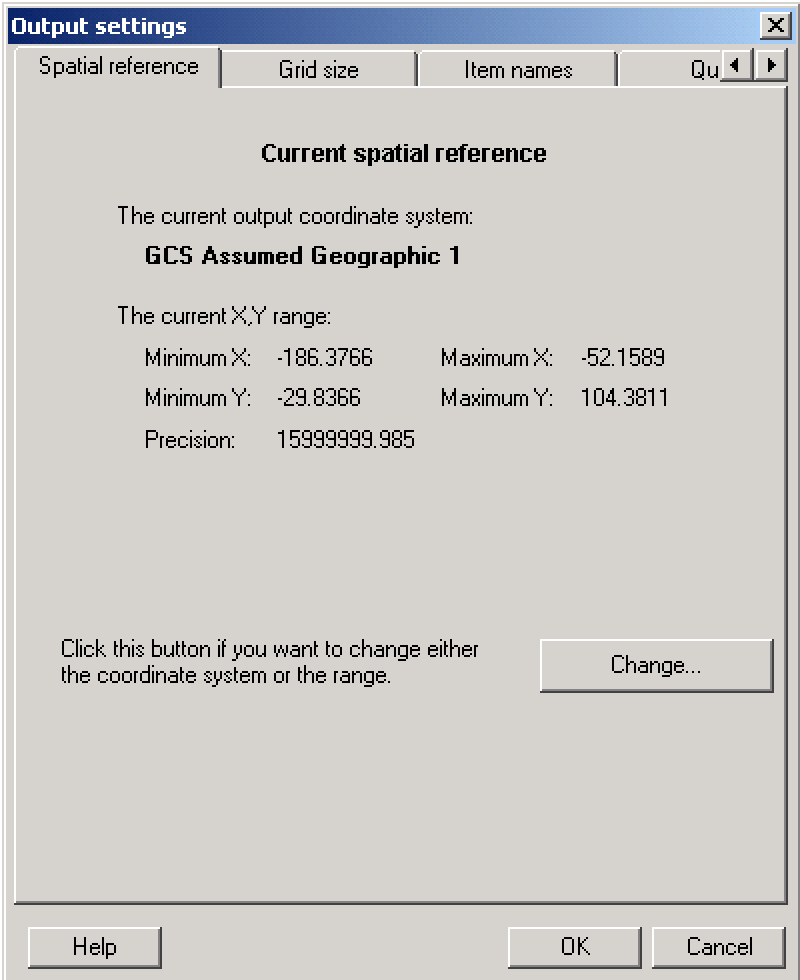


Leave the third option "*Select an existing feature dataset…*" empty

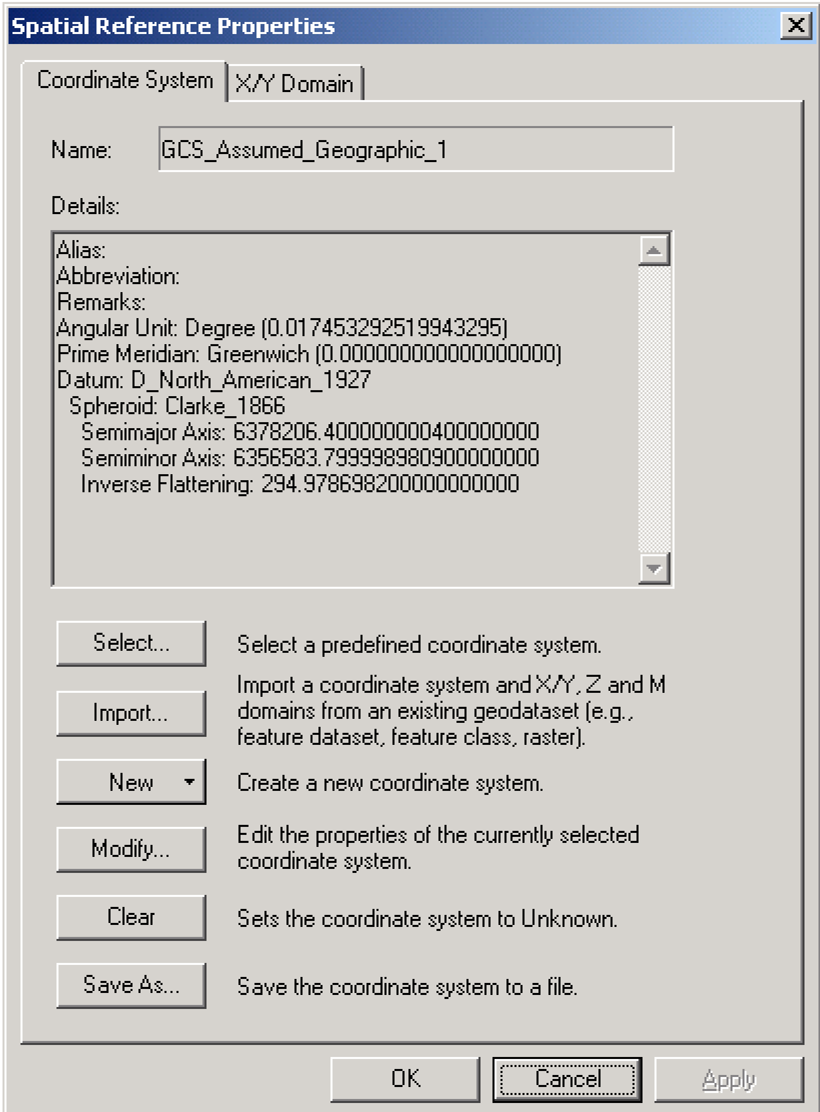
To change the name of the Out put feature class modify the edit box under "*Select an existing feature dataset…*". For example name has been changed to California_Site_Class_Hazus



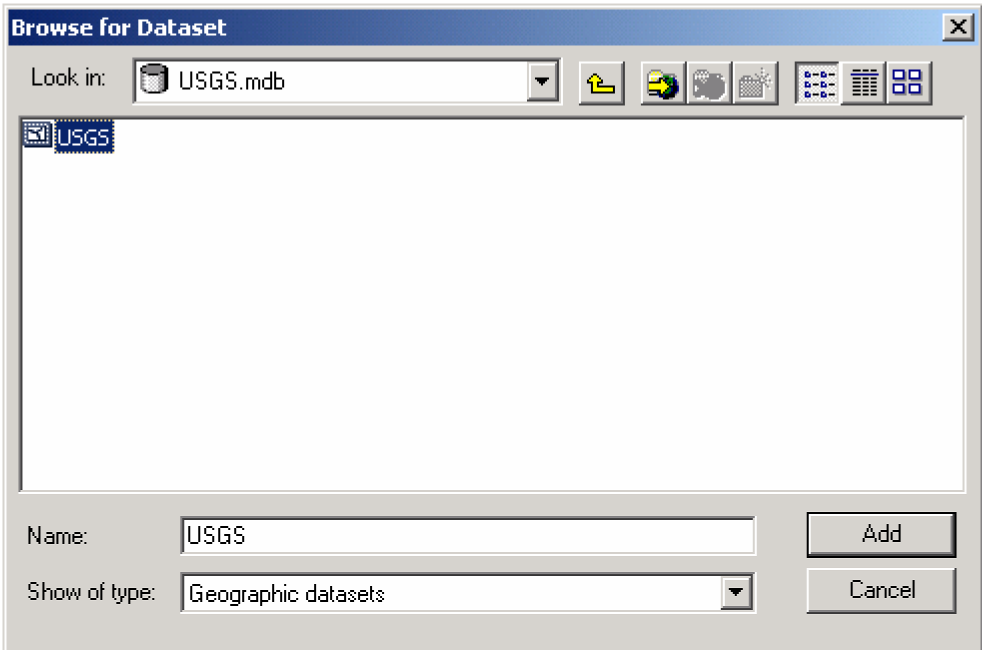
9) Now Click the Change Settings button, it shows setting options as follows:



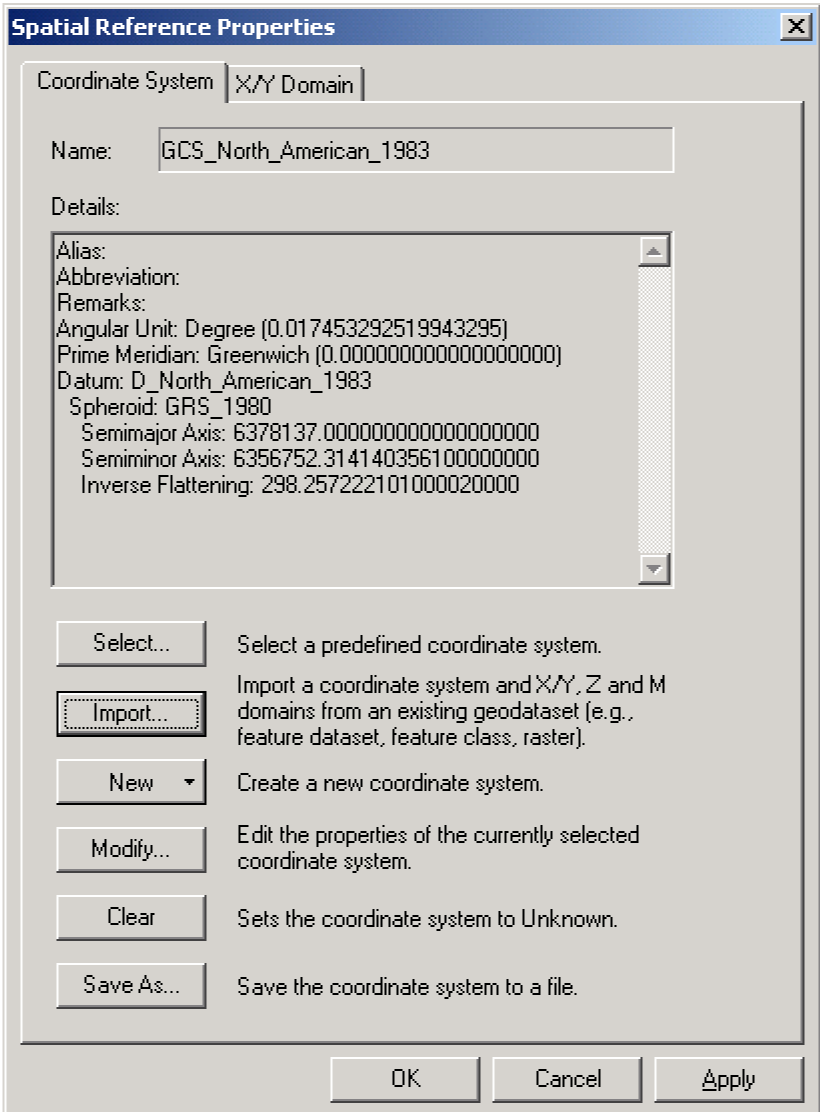
10) Click Change button on the Spatial Reference Tab



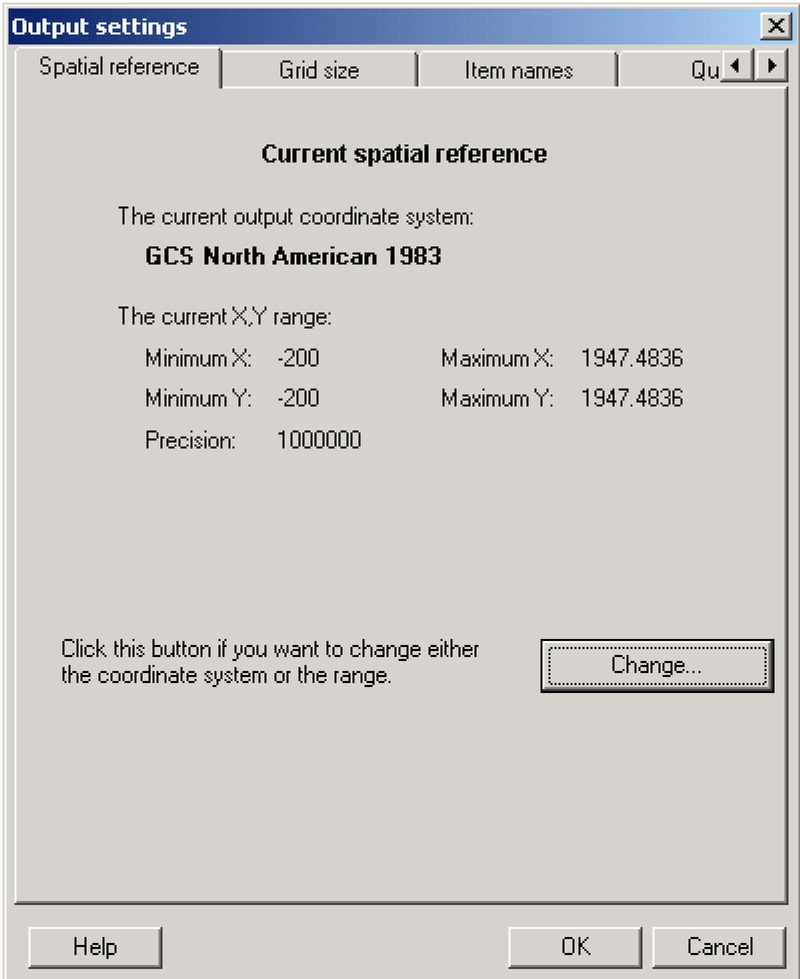
11) Click on Import Button and Browse to <HAZUS-MH>\DATA folder and select "USGS.MDB" and then select USGS feature class.
NOTE: <HAZUS-MH> represents the folder where HAZUS-MH is installed.



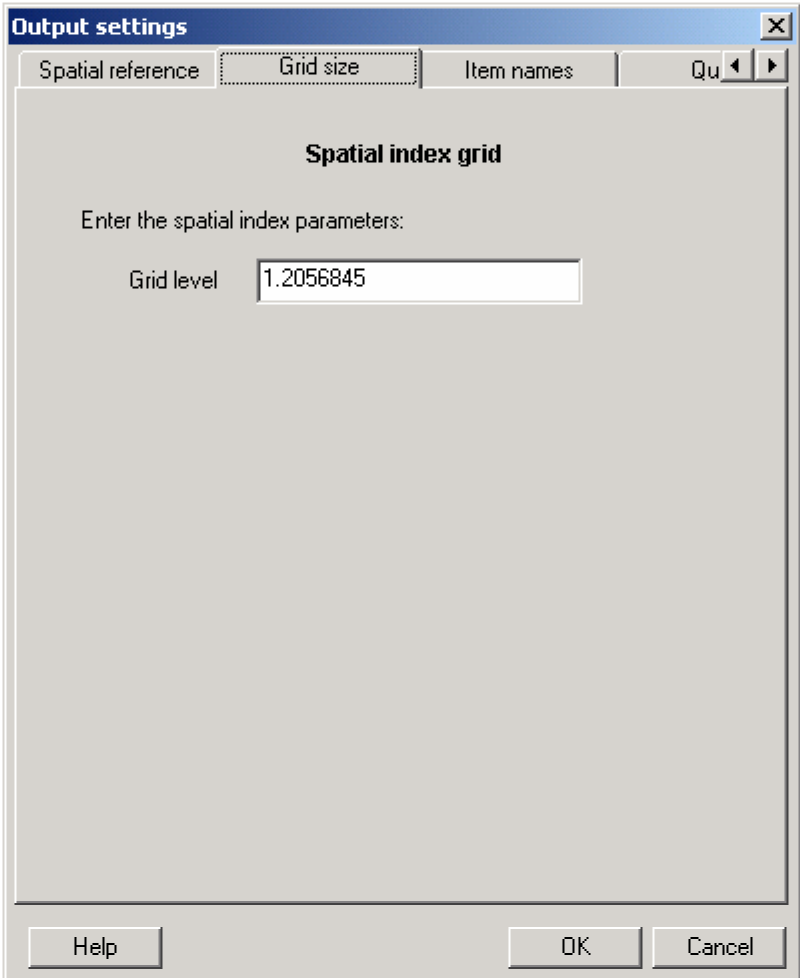
12) Click Add button and the new Settings will be reflected as follows:



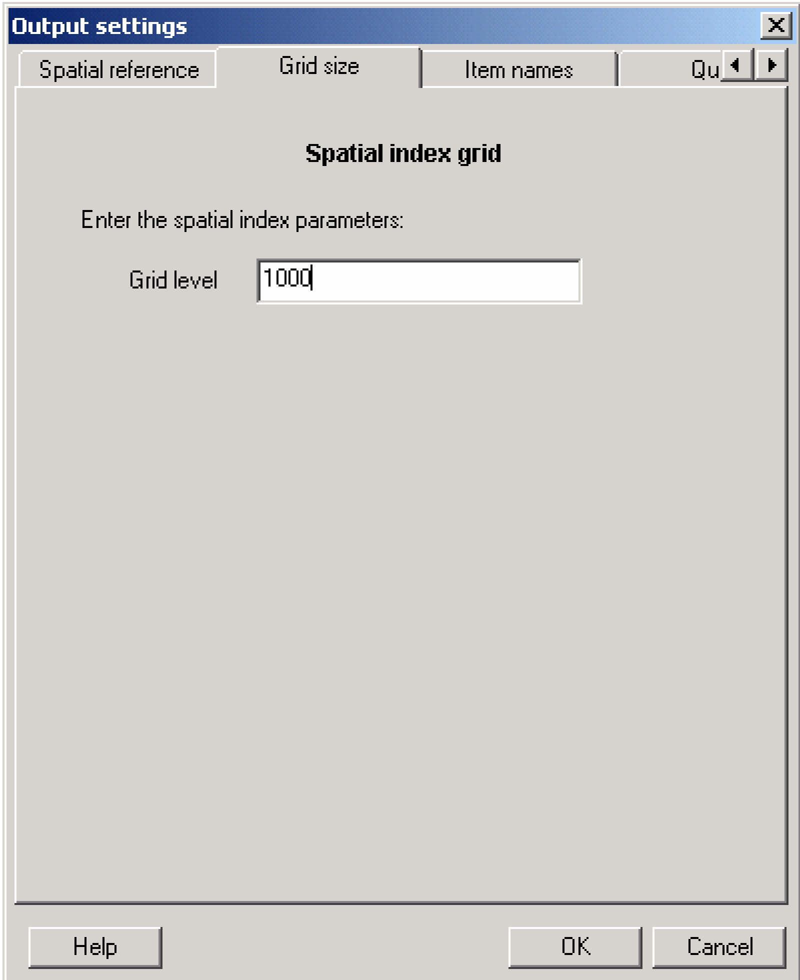
13) Click Apply and then OK and new Spatial reference Tab will be displayed as follows:



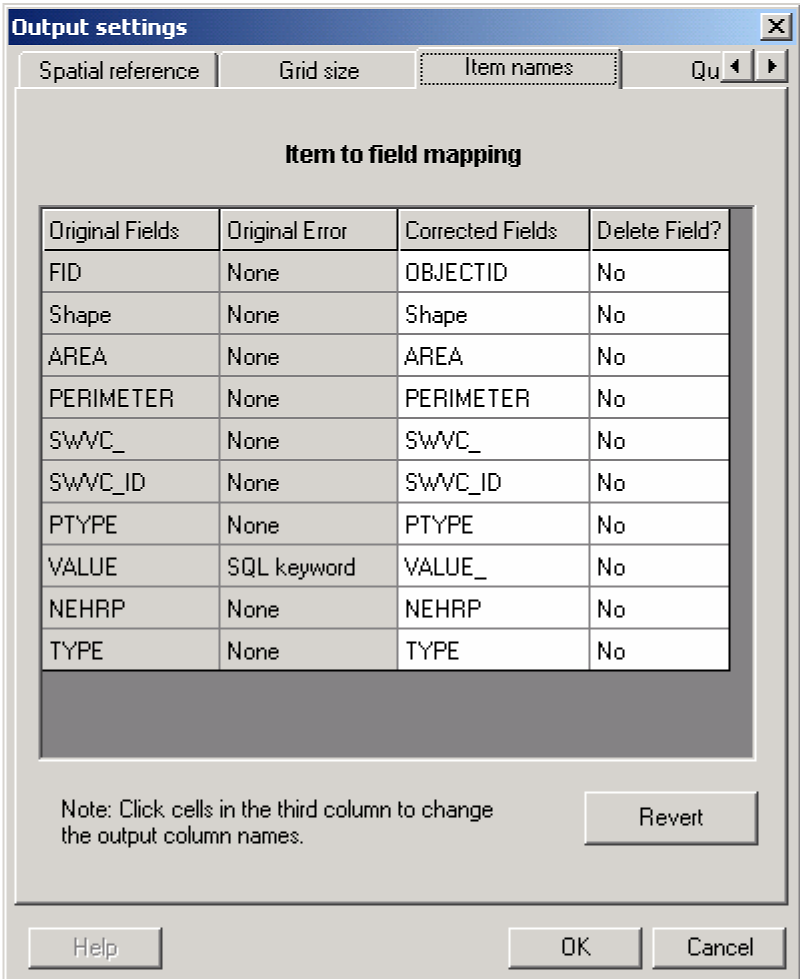
14) Now Click on the "GRID SIZE" tab, it will show the original Grid Size



Change Grid Level to 1000 as shown below:


Output settings
Spatial reference
Grid size
Item names
Qu
Spatial index grid
Enter the spatial index parameters:
Grid level
1000
Help
OK
Cancel

15) DON’T CLICK OK, instead Click on “Item Names” Tab which has the details of all the columns in the source feature class or shape file.



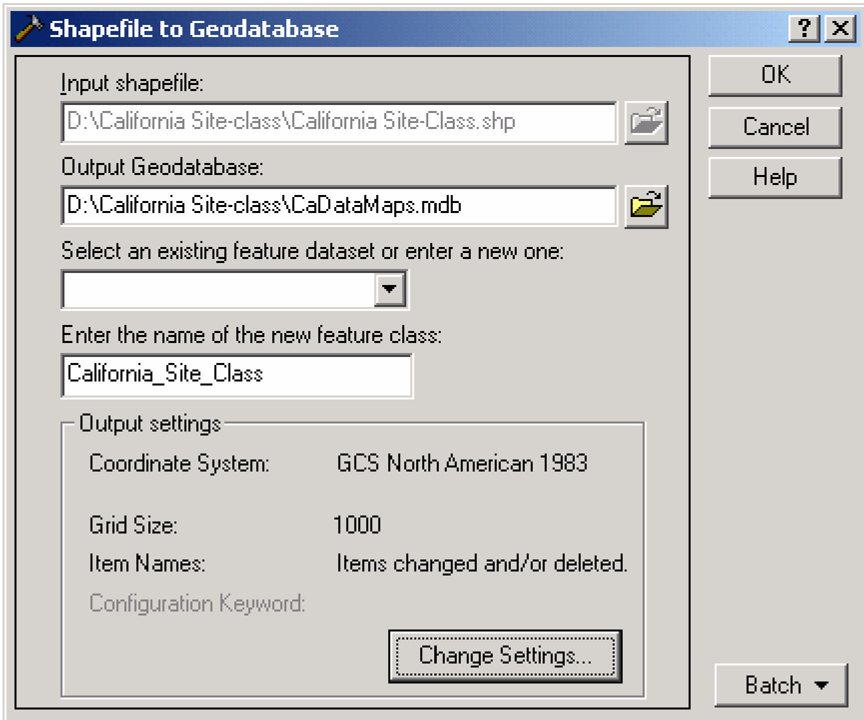
16) Now change the Setting under *Delete Field* column to YES for all fields other than FID (Object Id), Shape and field that has shaking values.

The following table summarizes the name of the field that has the shaking values, its data type and the range of values that HAZUS-MH expects. These should be used in the *Corrected Fields* column in the above dialog for all the shake maps.

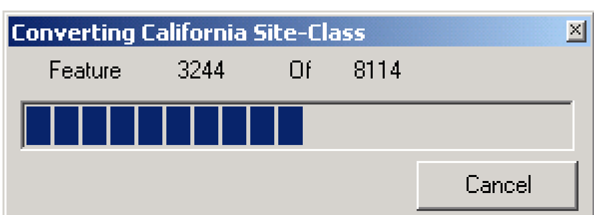
S. N	Type of Map	Correct Field Name	Field Type	Valid Values
1	All user defined Scenario Maps (Shake Maps)	ParamValue	Decimal	Values must be Greater than 0

So in our example the ***NEHRP*** field is the field that has the shaking values, so the *Corrected Field* corresponding to the *Original Field* NEHRP will be modified to **ParamValue (Decimal data type)** that is expected by HAZUS-MH for user defined ground shaking maps.

17) Now Click OK and on next screen which is same as



Click OK, it will show the progress bar while exporting



Once the Progress bar disappears, Export is over and the map has been successfully converted for use with HAZUS-MH..

Appendix K: GeoDatabase based Hazard Data Maps

K.1 Introduction

K.1.1 Purpose

The goal of the document is to show how the Hazard (Soil, Liquefaction, Landslide and Water Depth) Maps based on shp files could be converted into GeoDatabase based Hazard Maps.

K.1.2 Scope

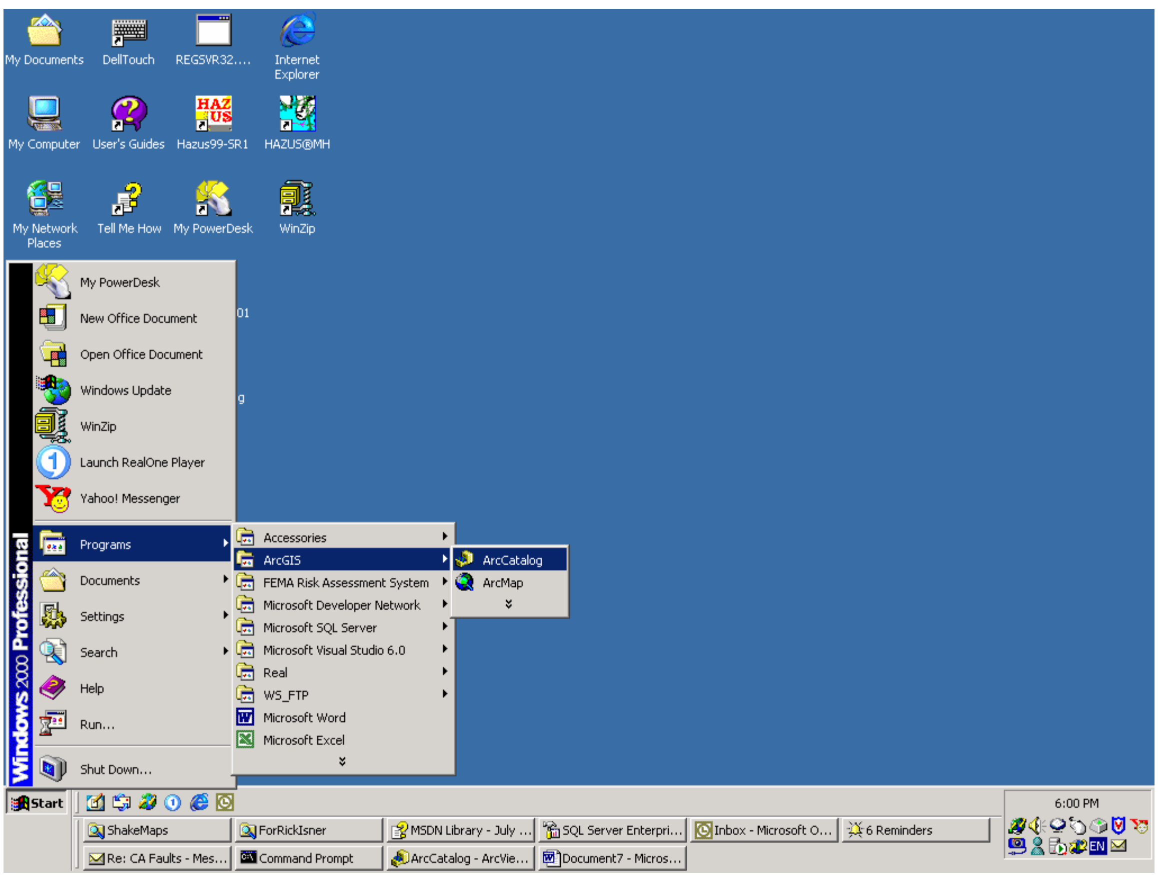
This document describes how SHP file based Hazard Maps could be converted into GeoDatabase based Hazard Maps in a step by step way. The focus is entirely on what is important to make the new GeoDatabases work with HAZUS-MH. This document should not be used as a resource for converting SHP files to GeoDatabases.

K.2 Prerequisites

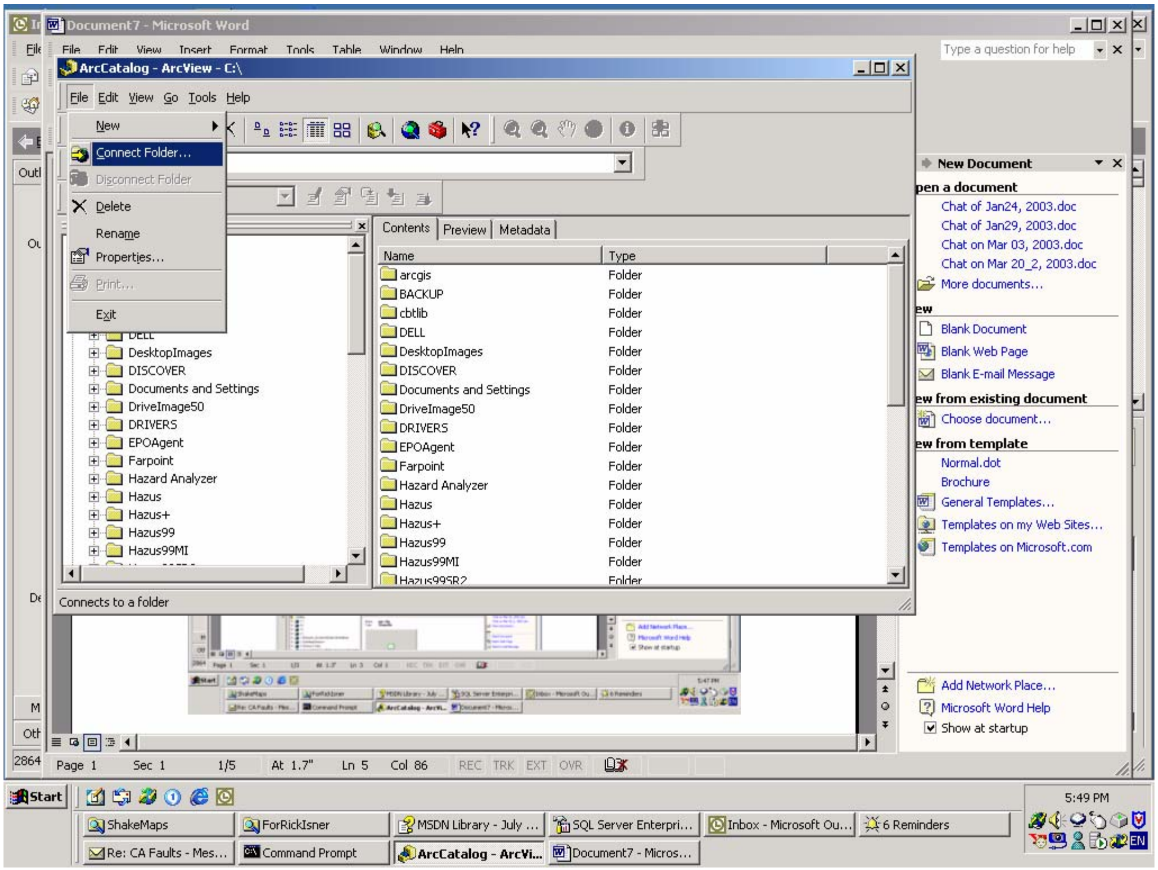
ArcGIS 9.0 (ArcMap and ArcCatalog) should be installed on the computer.

K.3 Creating GeoDatabase based Hazard Data Maps

1) Launch ArcCatalog from the Start menu.

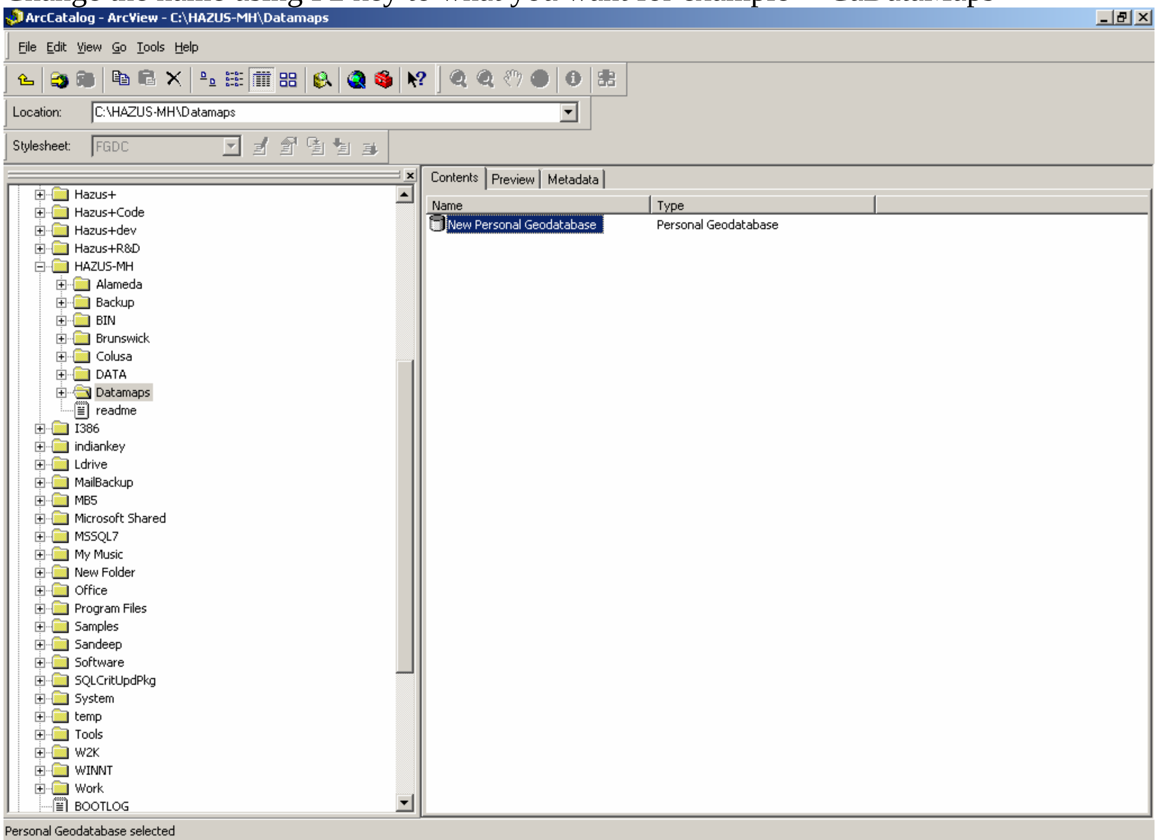


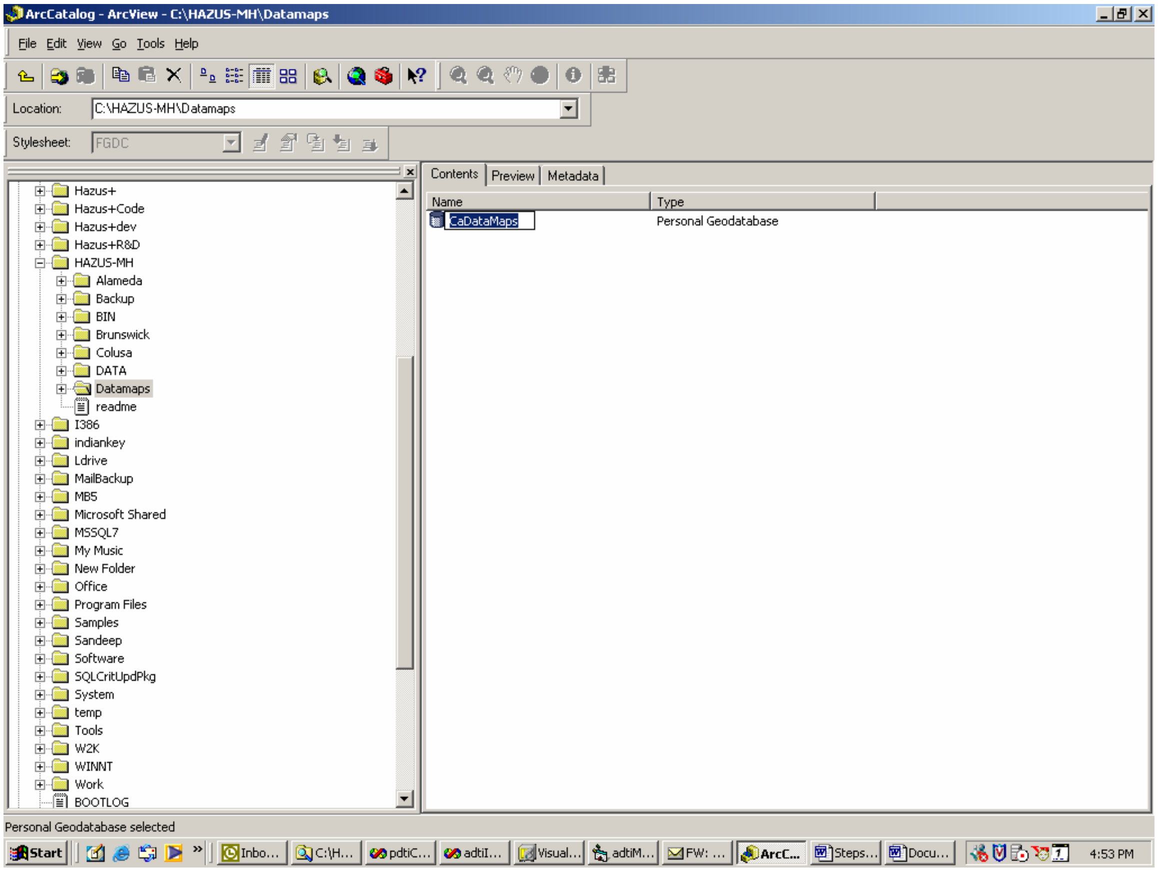
2) Click on the folder where the new Geo-Database is to be created. In case the folder is not available in ArcCatalog click on **File>Connect Folder** menu and select the folder where the Geo-Database is to be created. Once OK button is pressed on that dialog the folder will be visible in ArcCatalog



3) Select the Folder in TOC of the Arc catalog where the Geo-Database is to be created (the one added in the above step), Click on **File>New>Personal GeoDatabase** menu to create the new personal geodatabase.
By default the name appears as “New Personal Geodatabse”

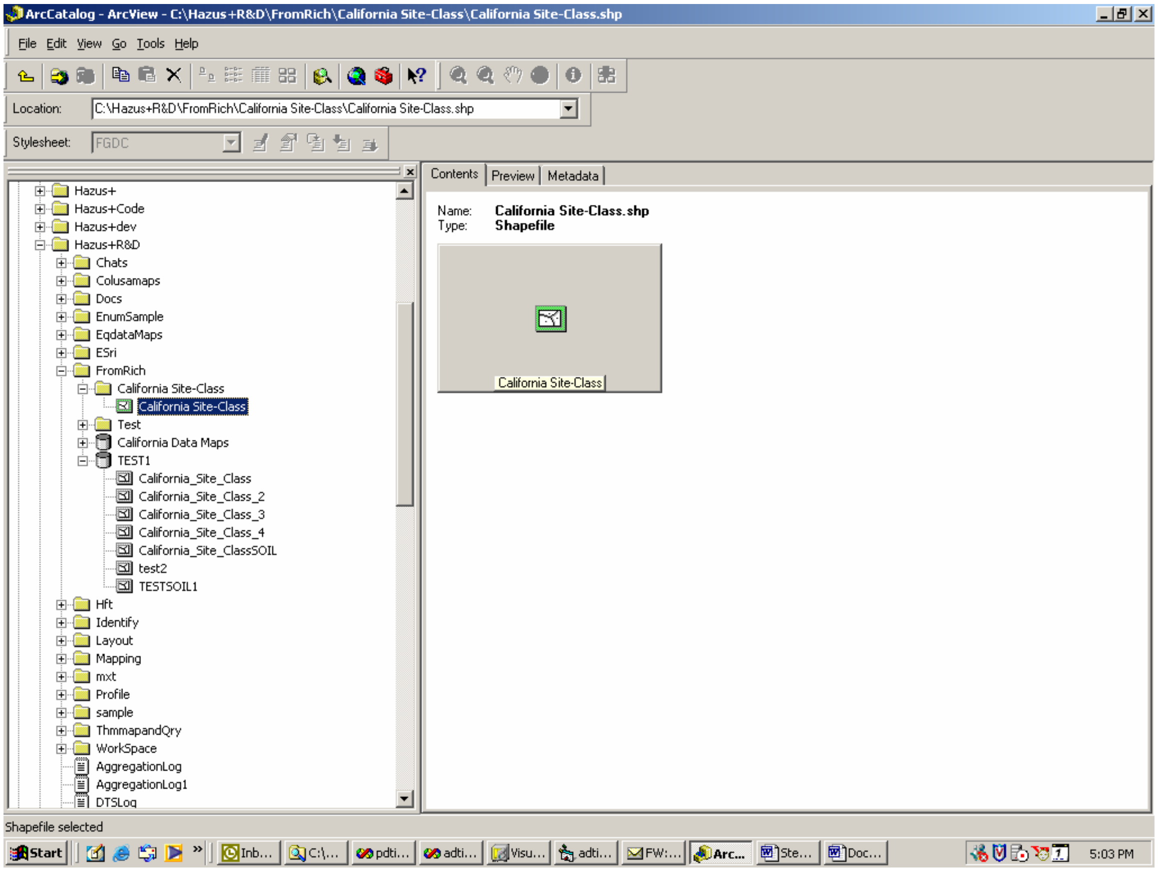
Change the name using F2 key to what you want for example “CaDataMaps”



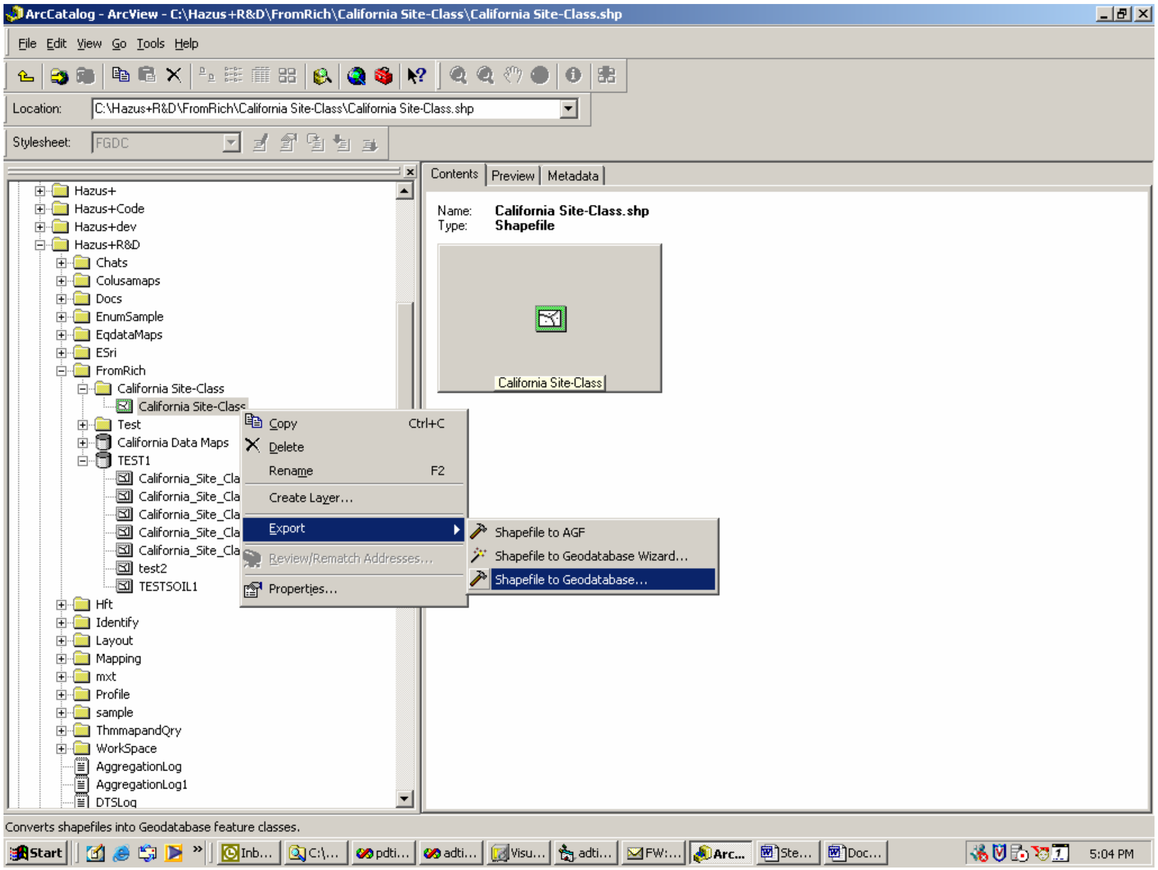

ArcCatalog - ArcView - C:\HAZUS-MH\Datamaps
File Edit View Go Tools Help
Location: C:\HAZUS-MH\Datamaps
Stylesheet: FGDC
Hazus+
Hazus+Code
Hazus+dev
Hazus+R&D
HAZUS-MH
Alameda
Backup
BIN
Brunswick
Colusa
DATA
Datamaps
readme
I386
indiankey
Ldrive
MailBackup
MB5
Microsoft Shared
MSSQL7
My Music
New Folder
Office
Program Files
Samples
Sandeep
Software
SQLCritUpdPkg
System
temp
Tools
W2K
WINNT
Work
BOOTLOG
Contents
Preview
Metadata
Name
Type
CaDataMaps
Personal Geodatabase
Personal Geodatabase selected
Start
4:53 PM

4) Select the folder where the hazard data maps are located in ArcCatalog's TOC. In the folder is not available in the TOC click on **File>Connect Folder** menu and select the folder where the hazard data maps are located, press the OK button and the folder will be visible in ArcCatalog's TOC.

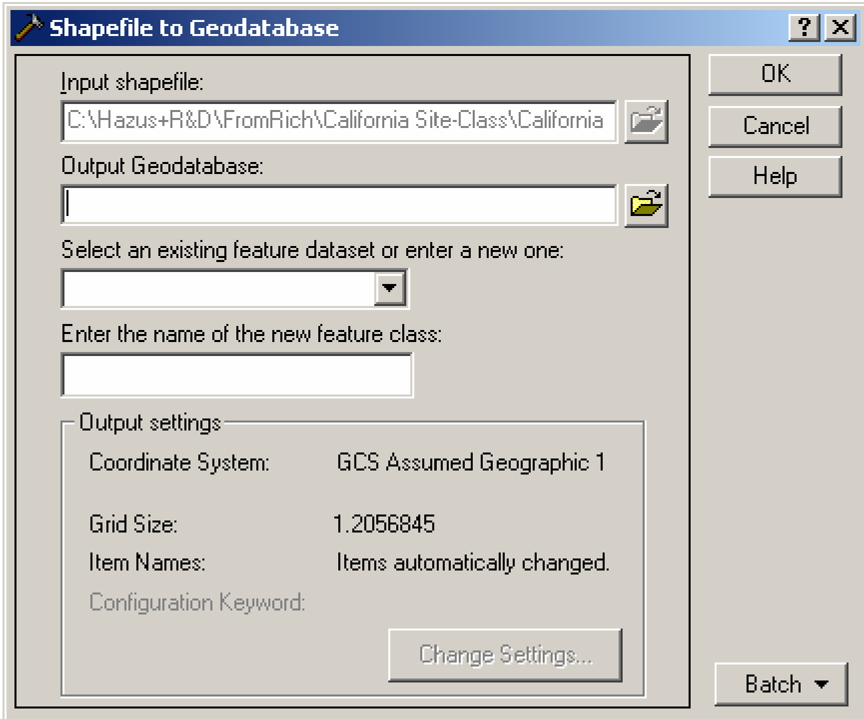
5) Select the Shape file which is to be exported under the connected folder in TOC as shown



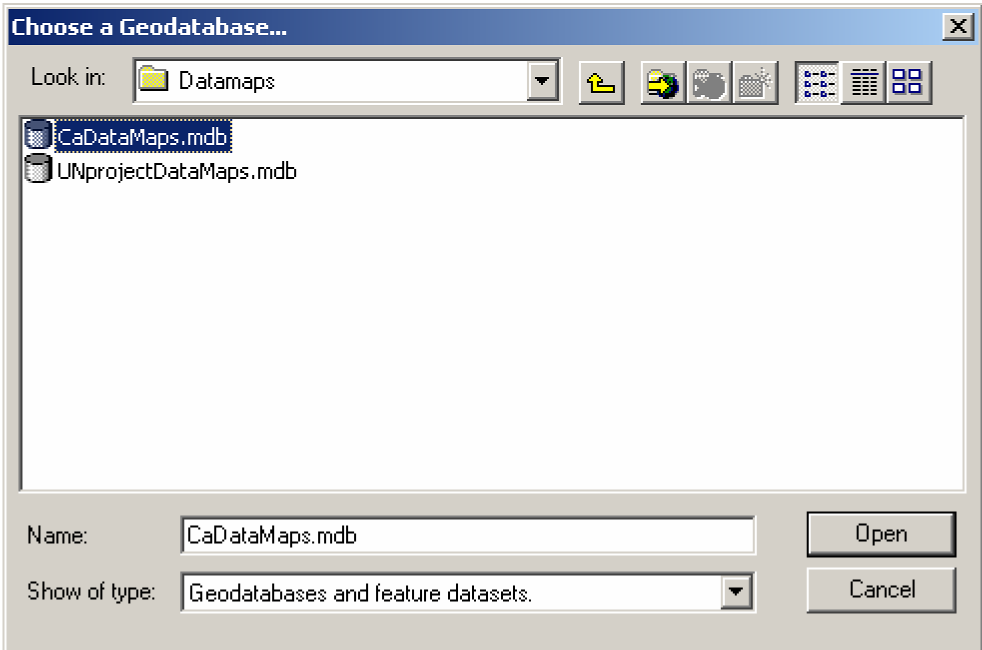
6) Right click and select third option under Export (shape file to geo database) as shown



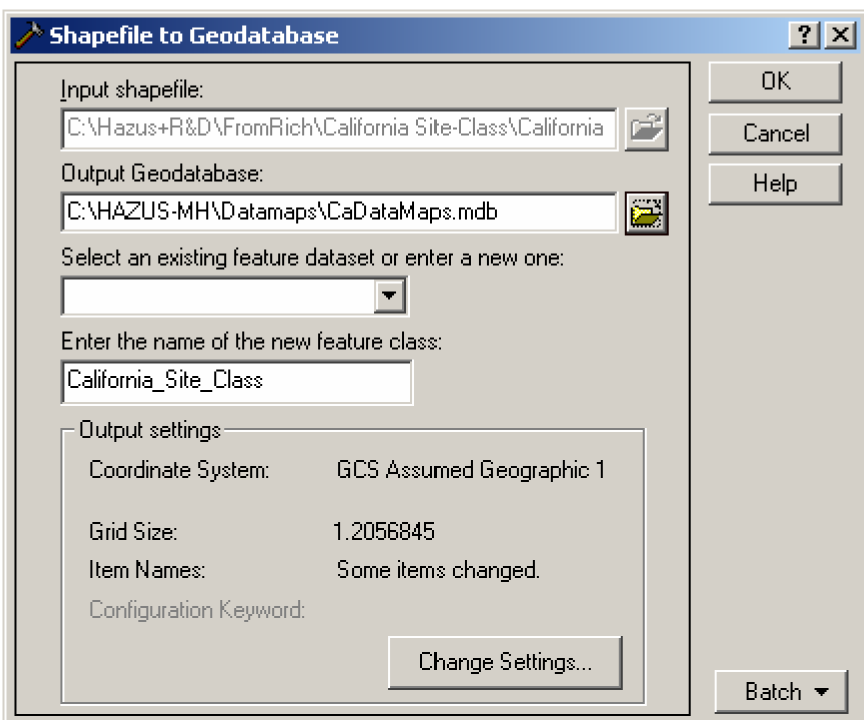
7) The Export option will show a dialog as follows:



8) Click on the browse button for the Out put Geo data base and select the geo database created in step 3.

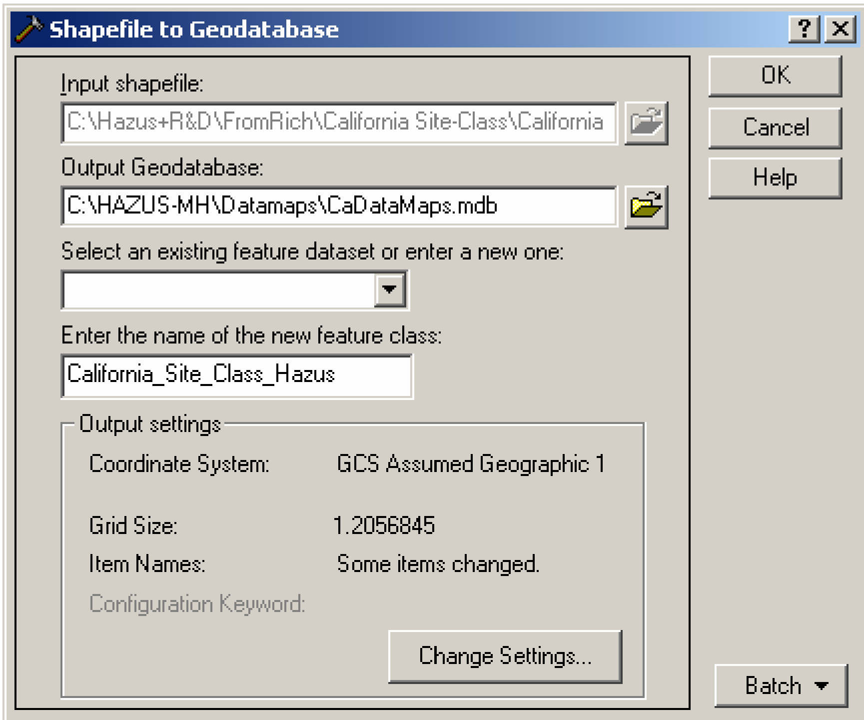


Clicking Open button will launch the following dialog:

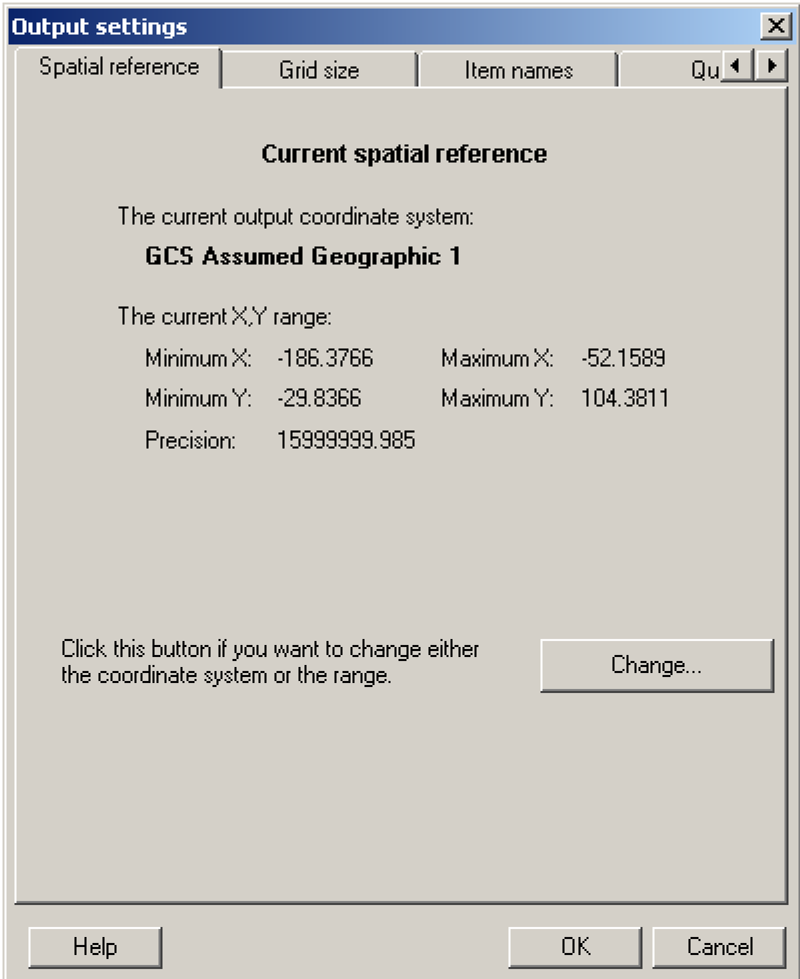


Leave the third option “*Select an existing feature dataset…*” empty

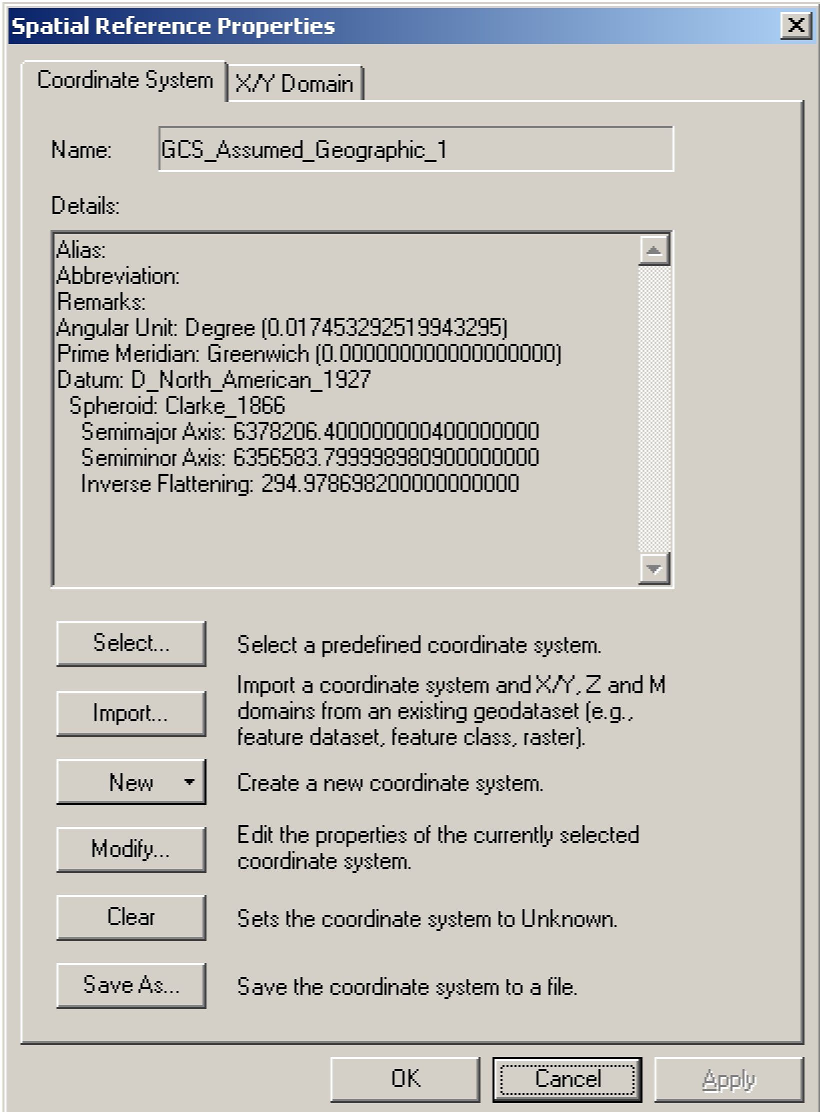
To change the name of the Out put feature class modify the edit box under "*Select an existing feature dataset…*". For example name has been changed to California_Site_Class_HAZUS



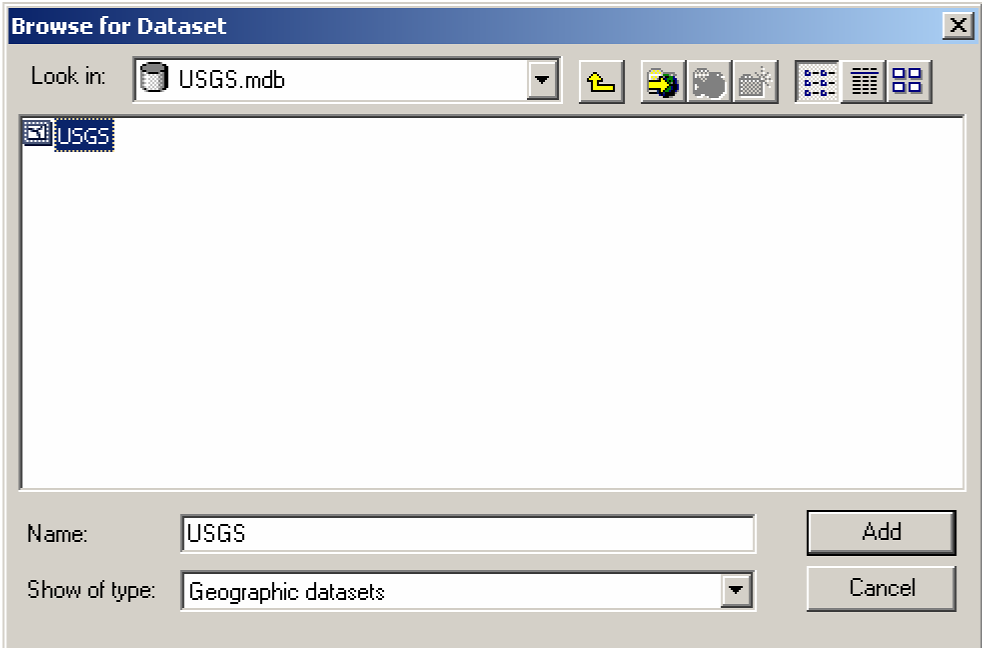
9) Now Click the Change Settings button, it shows setting options as follows:



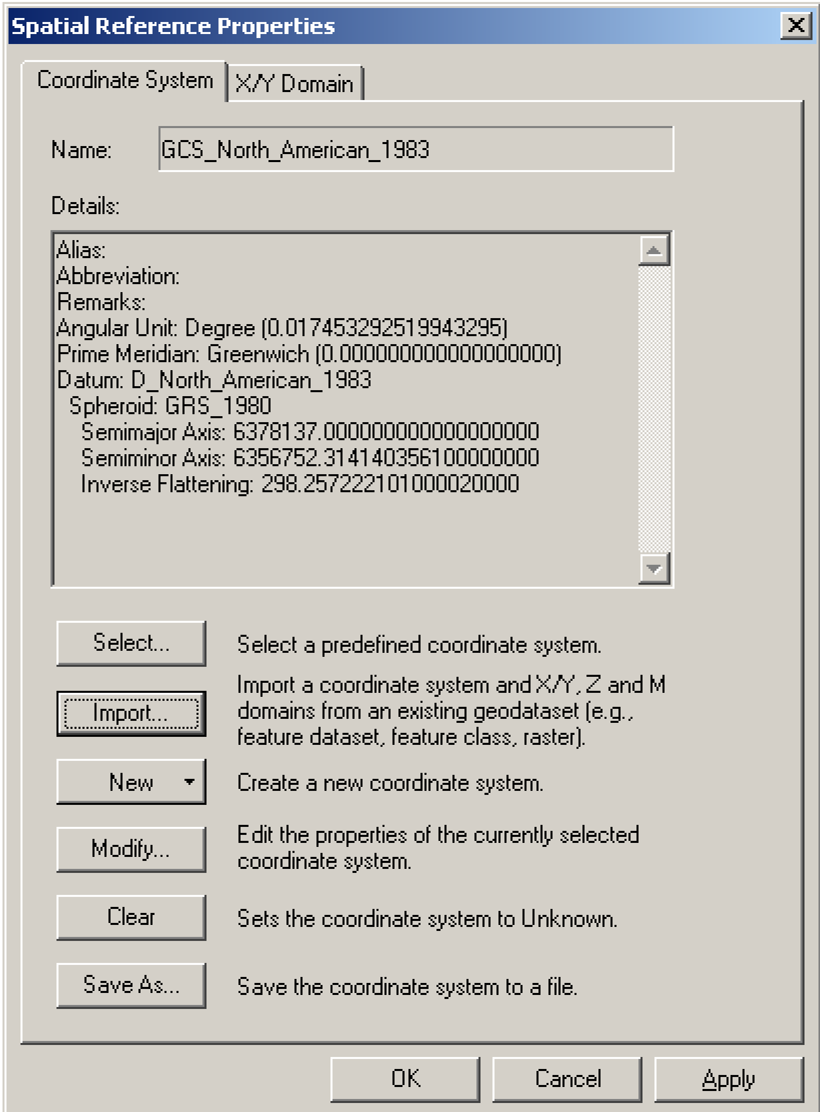
10) Click Change button on the Spatial Reference Tab



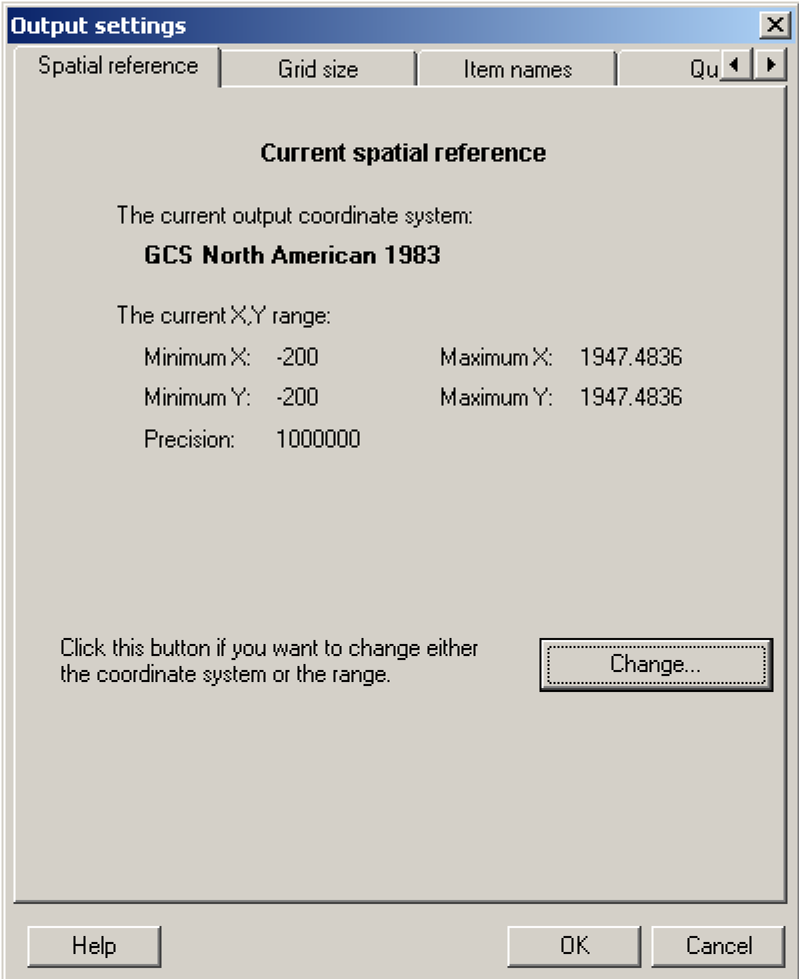
11) Click on Import Button and Browse to <HAZUS-MH>\DATA folder and select "USGS.MDB" and then select USGS feature class.
NOTE: <HAZUS-MH> represents the folder where HAZUS-MH is installed.



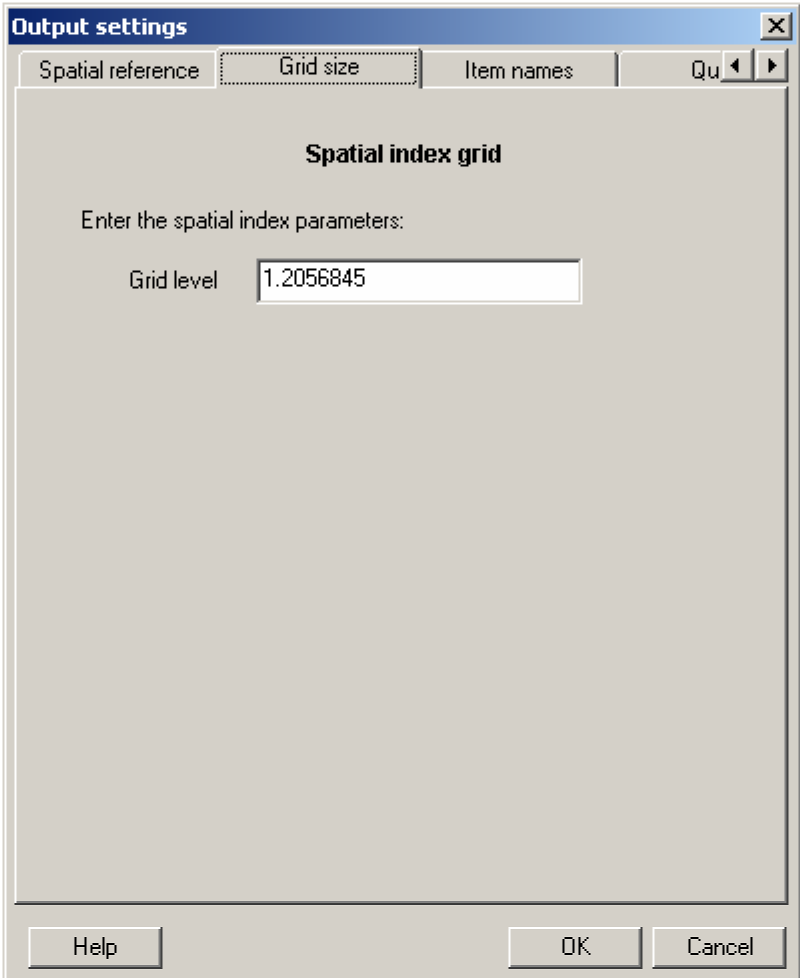
12) Click Add button and the new Settings will be reflected as follows:



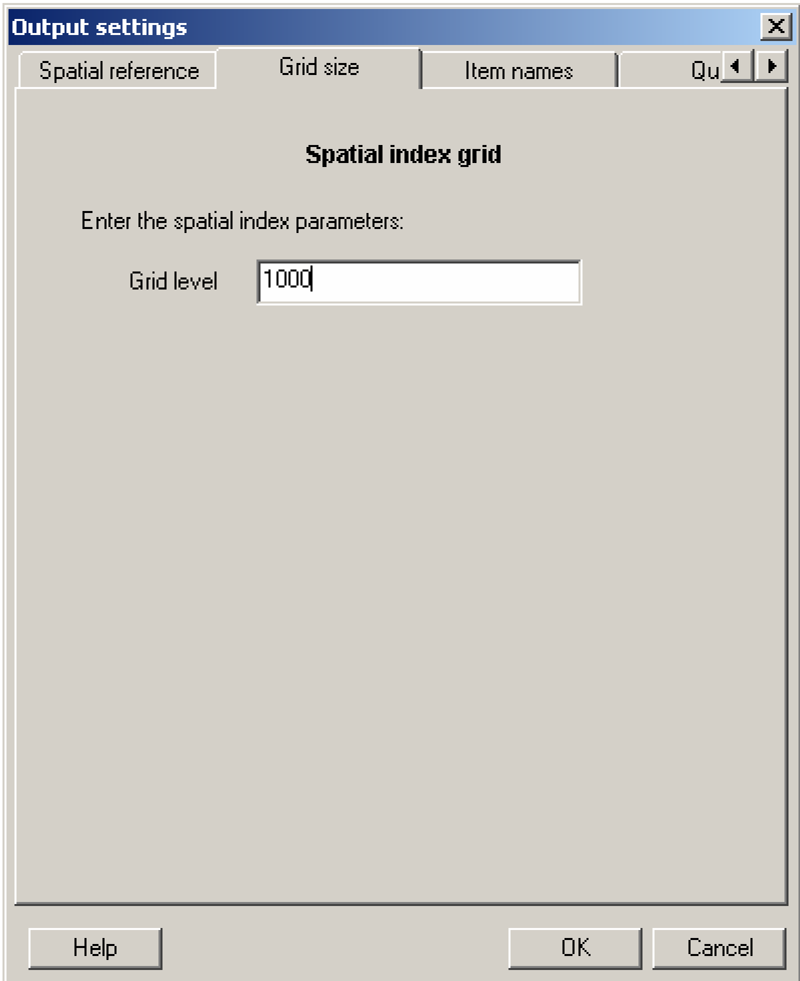
13) Click Apply and then OK and new Spatial reference Tab will be displayed as follows:



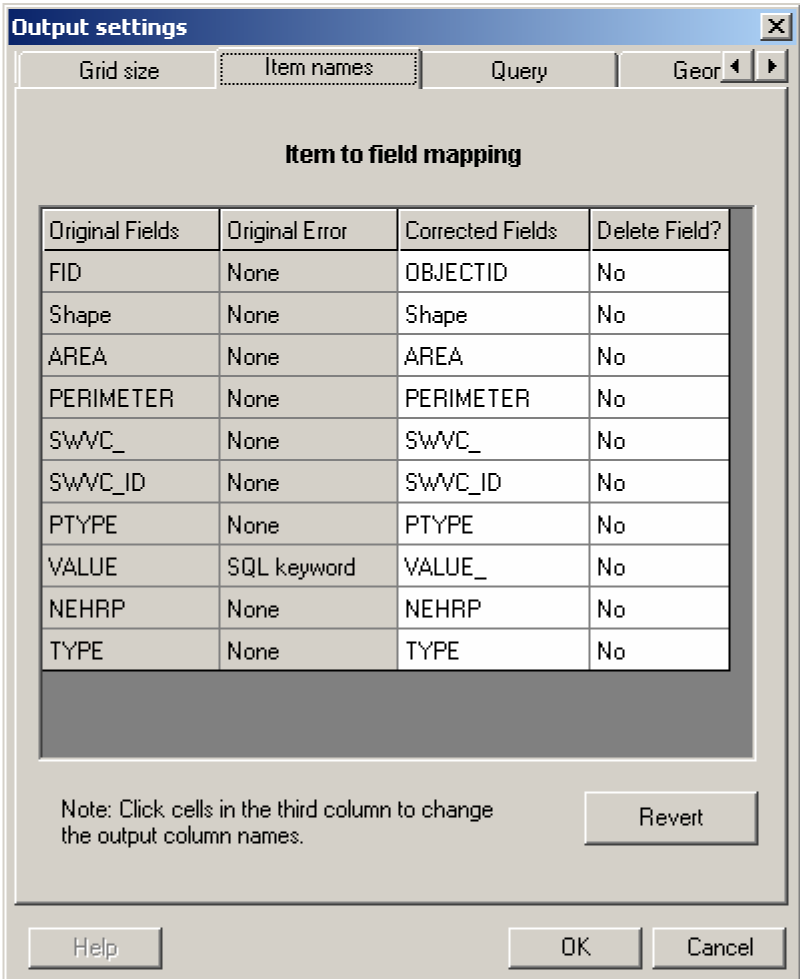
14) Now Click on the "GRID SIZE" tab, it will show the original Grid Size



Change Grid Level to 1000 as shown below:


Output settings
Spatial reference
Grid size
Item names
Qu
Spatial index grid
Enter the spatial index parameters:
Grid level
1000
Help
OK
Cancel

15) DON'T CLICK OK, instead Click on "Item Names" Tab which has the details of all the columns in the source feature class or shape file.

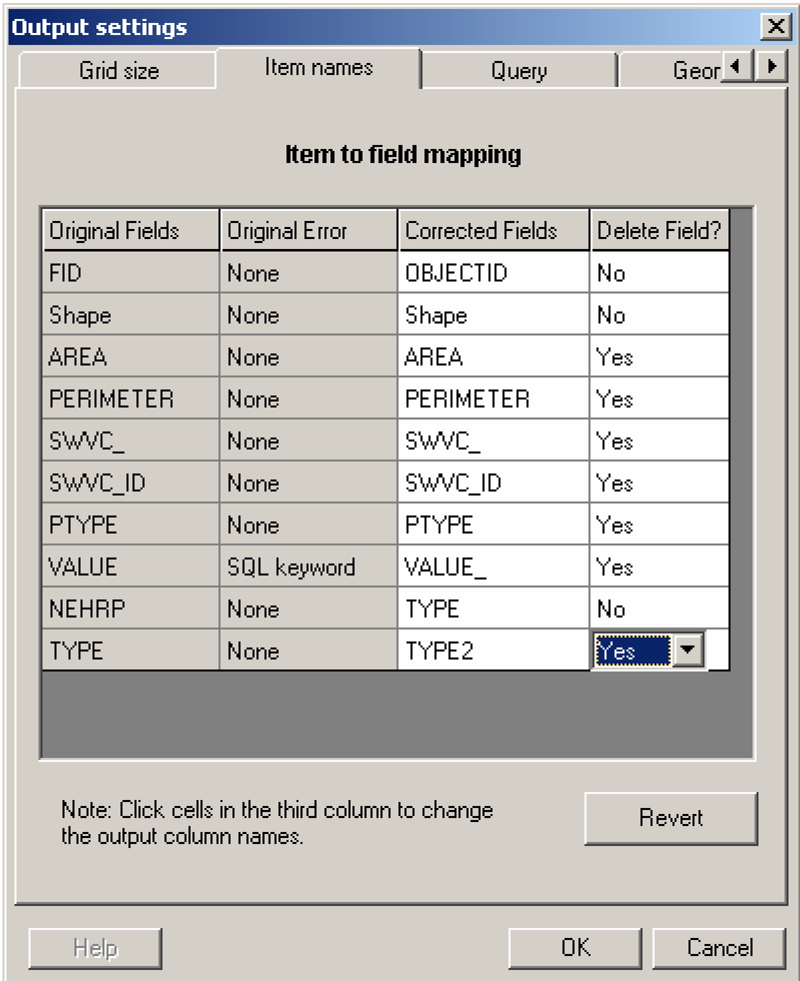


16) Now change the Setting under *Delete Field* column on the dialog to YES for all fields other than
FID (Object Id),
Shape and
Hazard Specific field.

The following table summarizes the various hazard specific fields names, their types and the ranges of values that HAZUS-MH expects. These should be used in the Corrected Fields column in the above dialog for the corresponding maps.

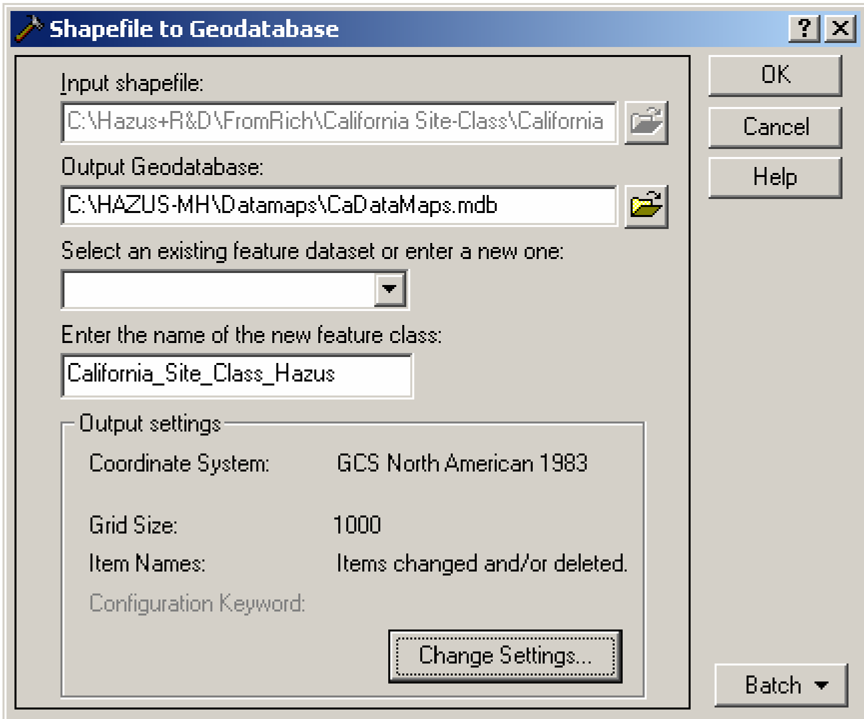
S. N	Type of Map	Correct Field Name	Field Type	Valid Values
1	SOIL	Type	Text (1)	A, B, C, D ,E
2	Liquefaction Susceptibility Map	Type	Numeric (1,0)	0 to 5
3	Landslide Susceptibility map	Type	Numeric (2,0)	0 to 10
4	Water Depth map	Type	Decimal	Values must Greater than 0

In our example, which is a soil map, the ***NEHRP*** field represents the ***TYPE*** for the Soil map, so the *Corrected Field* corresponding to the *Original Field* NEHRP was modified to **TYPE** that is expected by HAZUS-MH for soil type. This is shown in the next figure.

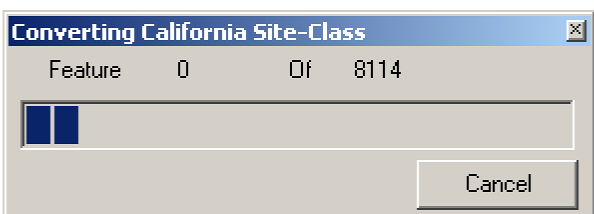


Similarly in case of Liquefaction Map the name of the field that contains the liquefaction susceptibility category should be **TYPE Numeric(1, 0),** in case of Landslide Map the name of the field that contains the landslide susceptibility category should be **TYPE Numeric(1, 0)** and in case of Water Depth Map the name of the field that contains the water depth should be **TYPE Decimal.**

17) Now Click OK and on next screen which is same as



Click OK, it will show the progress bar while exporting



Once the Progress bar disappears, Export is over and the map has been successfully converted for use with HAZUS-MH..

Appendix L: ALOHA \ MARPLOT Integration with HAZUS-MH

L.1 Introduction

L.1.1 Purpose

The goal of the document is to show how Aloha/Marplot can be run from within HAZUS-MH and the results could be overlaid onto HAZUS-MH inventory and results.

L.1.2 Scope

This document describes how Aloha/Marplot could be launched from HAZUS-MH and the results from Aloha/Marplot could be brought into HAZUS-MH for overlay analysis. This document doesn't explain how to run Aloha / Marplot.

L.2 Prerequisites

HAZUS-MH doesn't install Aloha/Marplot as part of its installation. Before Aloha/Marplot could be used from HAZUS-MH, the user needs to install Aloha and Marplot. Once Aloha and Marplot are installed HAZUS-MH automatically detects the application and launches it.

L.3 Running Aloha and Marplot from within HAZUS-MH

1. Start ***HAZUS-MH***, aggregate the appropriate region as per the requirement at county, block or at tract level.

2. Open the Region, from the menu; select the **Analysis |3rd party Models| ALOHA| Run.**

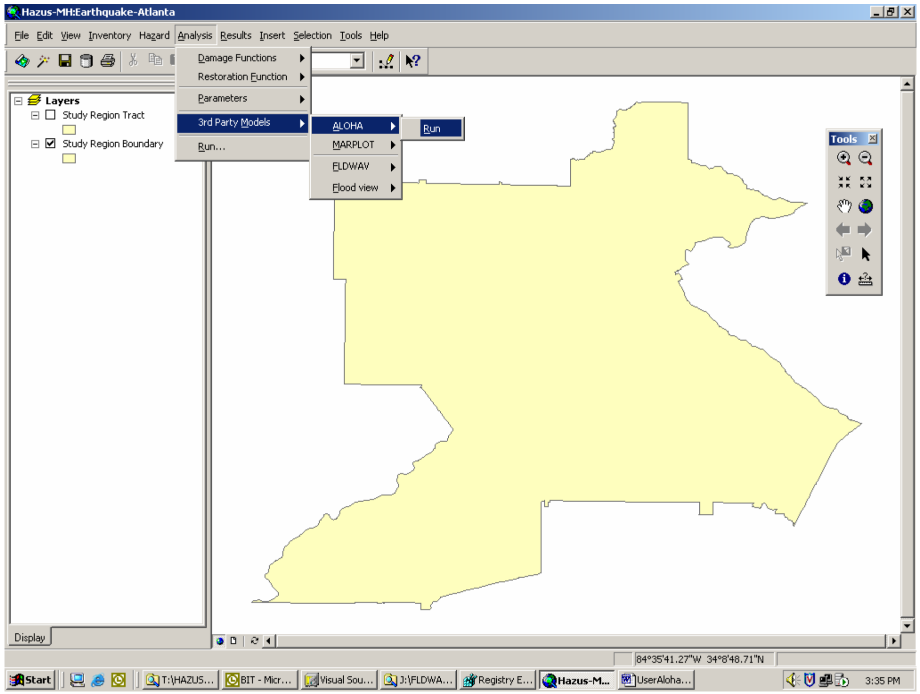


Figure L.1

3. ***HAZUS-MH*** will check whether the ***ALOHA*** program is installed or not. If you have installed then click yes. If not Click NO. Install ALOHA.

Figure L.2

When you click yes HAZUS-MH will search the ALOHA program and launch ALOHA as shown

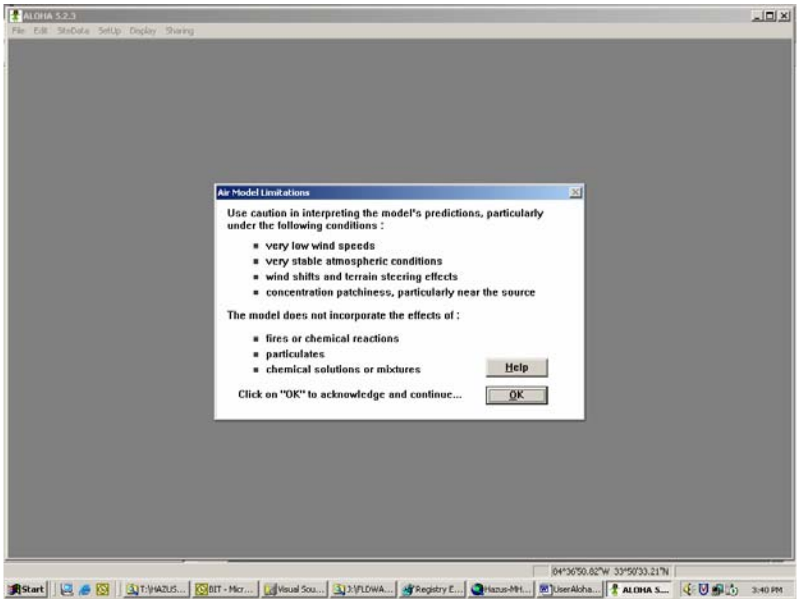


Figure L.3

4. Use Aloha for the Region you want (It should be a location within the study region which you have aggregated). Generate Foot Print files.
5. Once you have generated ALOHA outputs close Aloha application and select the **Analysis |3rd party Models| MARPLOT| Run**

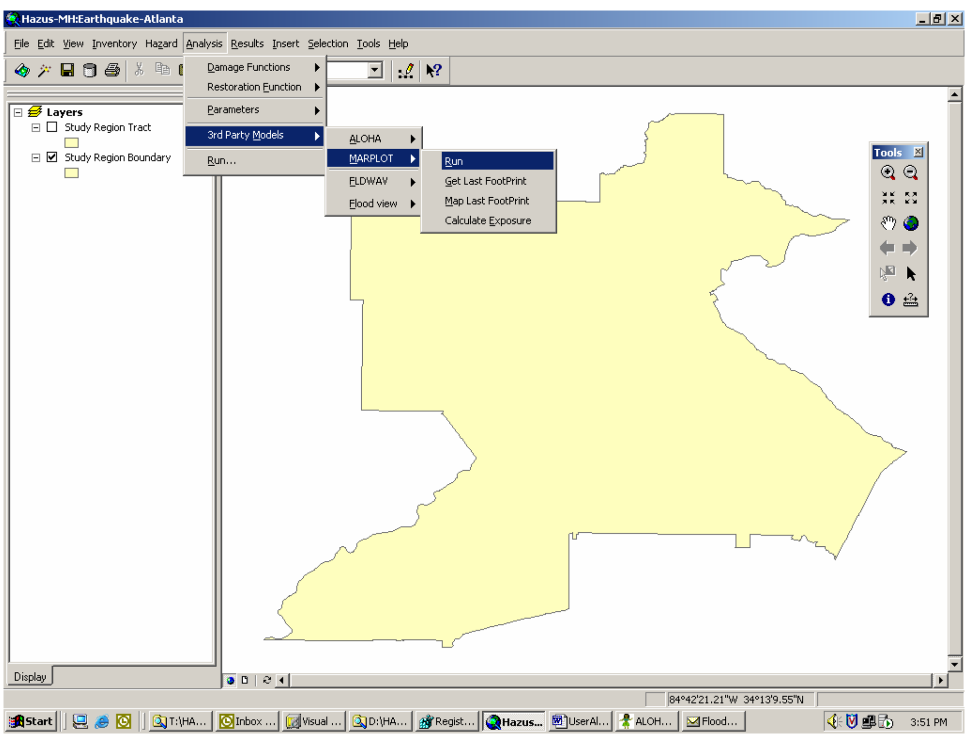


Figure L.4

6. ***HAZUS-MH*** will check whether the ***MARPLOT*** program is installed or not. If you have installed then click yes. If not Click NO. Install ***MARPLOT*** and Come Back.

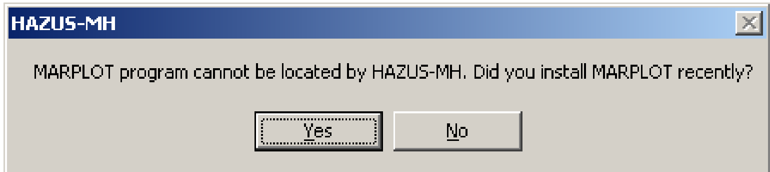


Figure L.5

When you click yes ***HAZUS-MH*** will search the MARPLOT program and launch MARPLOT as shown in Figure L.6 below.

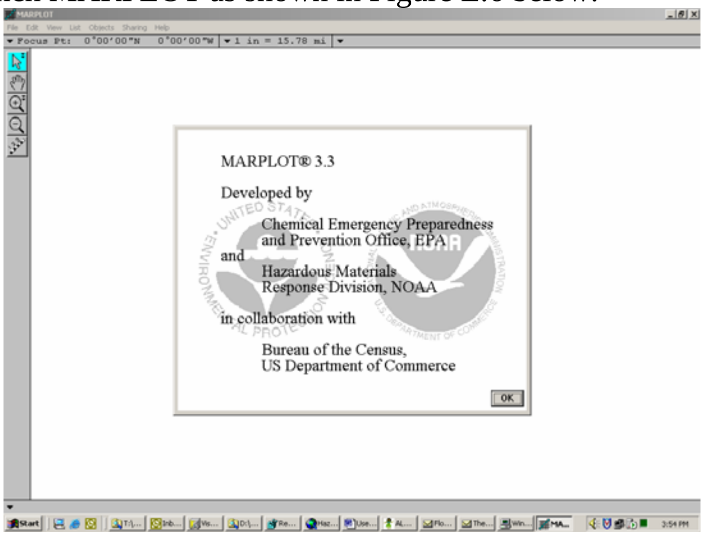


Figure L.6

7. Use Marplot and Import the Aloha Footprints in Marplot MAP at a location within your study region. Then select both the Polygons on Marplot map

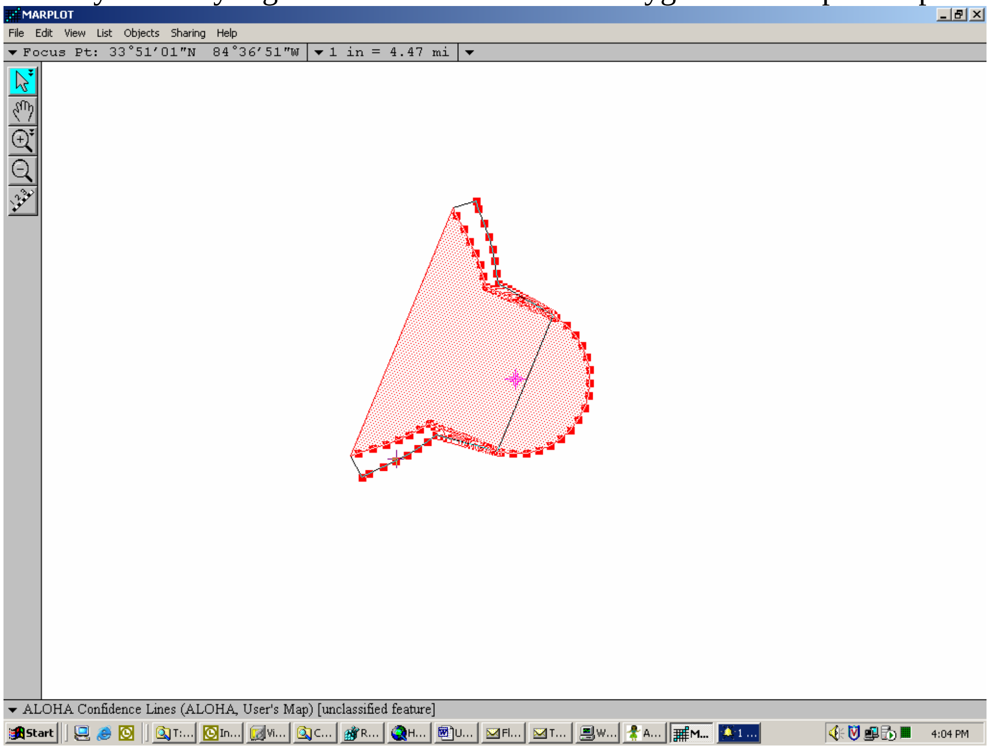


Figure L.7

8. Now Export to Marplot output using File-Export menu of Marplot as shown in Figure L.8.

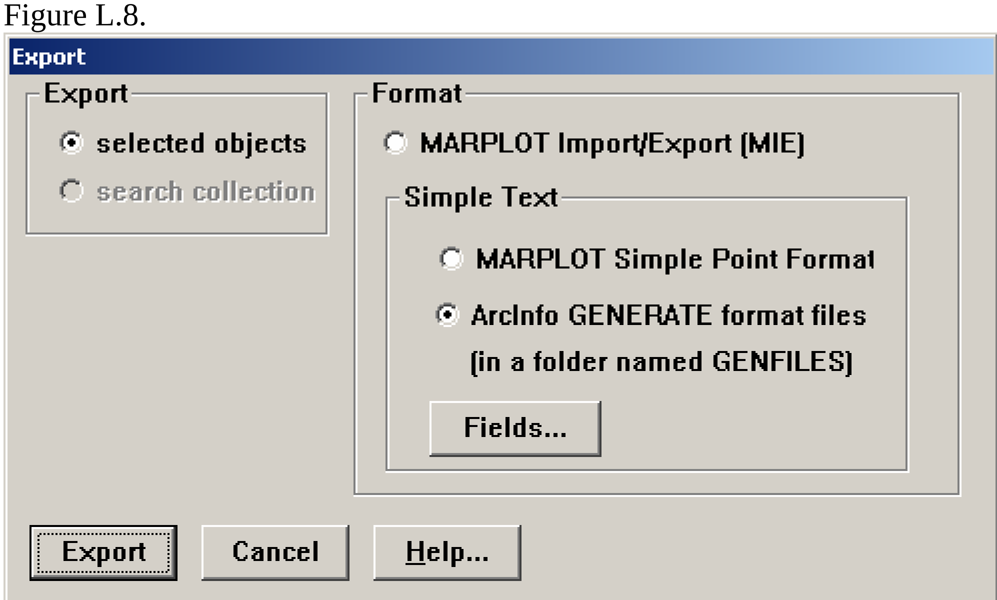


Figure L.8

9. Come Back to ***HAZUS-MH***. Select the **Analysis |3rd party Models| MARPLOT| Get Last FootPrint.**

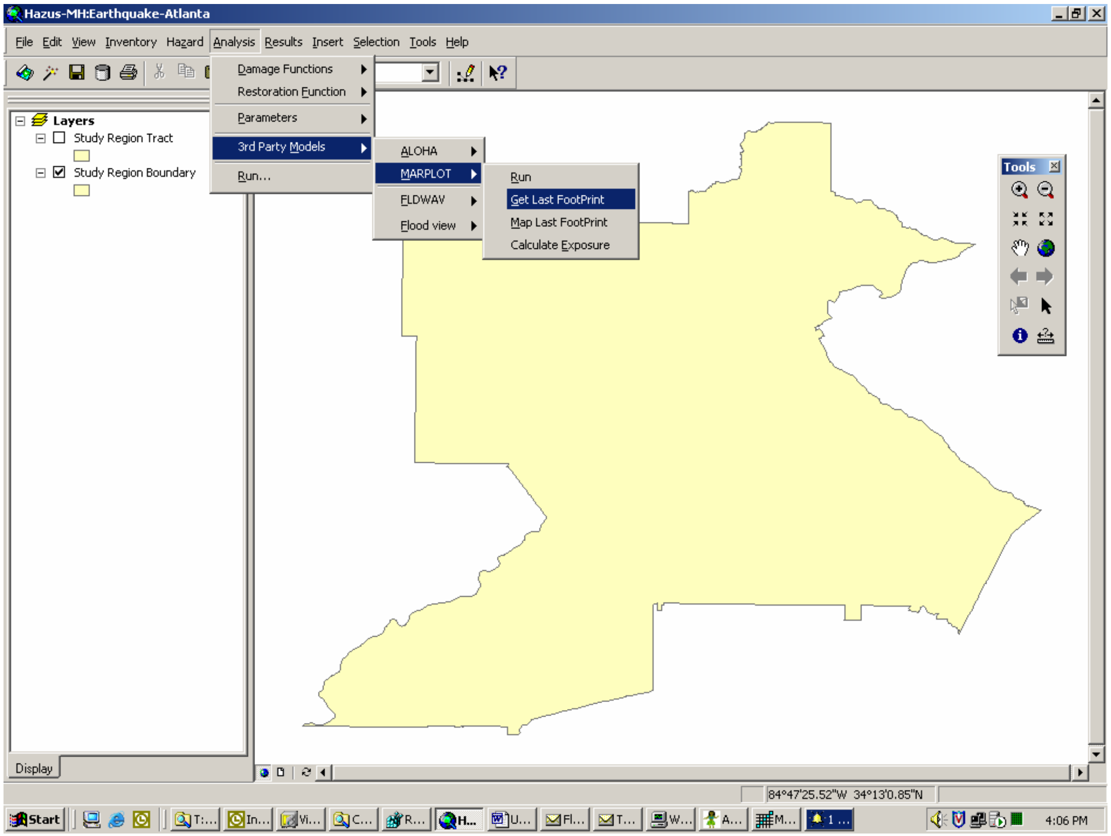


Figure L.9

This will bring the Marplot output in to your stuffy Region. If successful, ***HAZUS-MH*** will give message

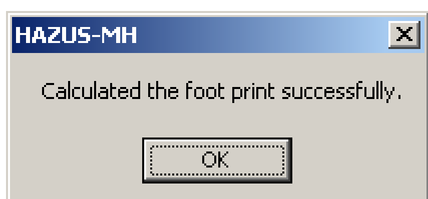


Figure L.10

10. To see footprint map, select the **Analysis |3rd party Models| MARPLOT| Map Last FootPrint**

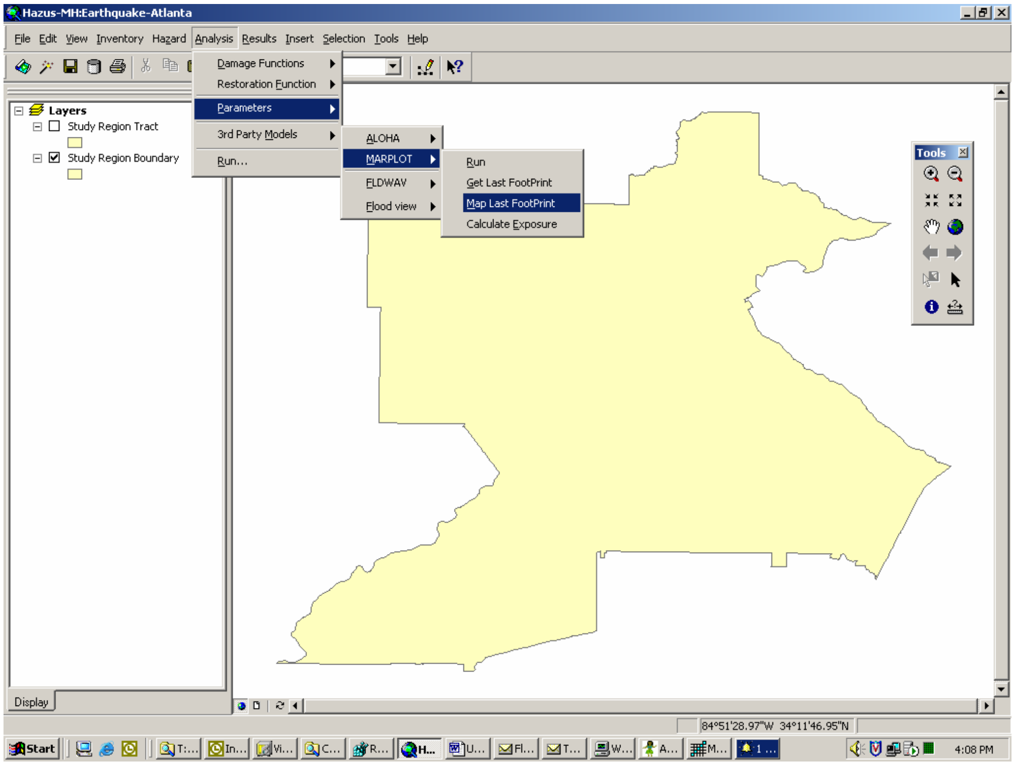


Figure L.11

11. ***HAZUS-MH*** will add the Marplot Layer as shown in Figure L.12.

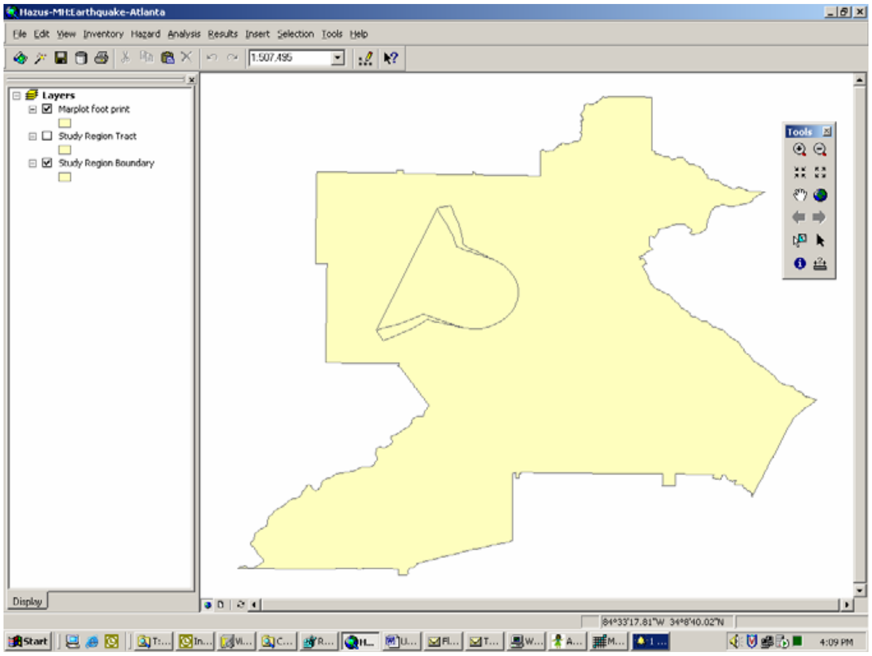


Figure L.12

12. To calculate Exposure under Marplot area select **Analysis |3rd party Models| MARPLOT| Calculate Exposure**

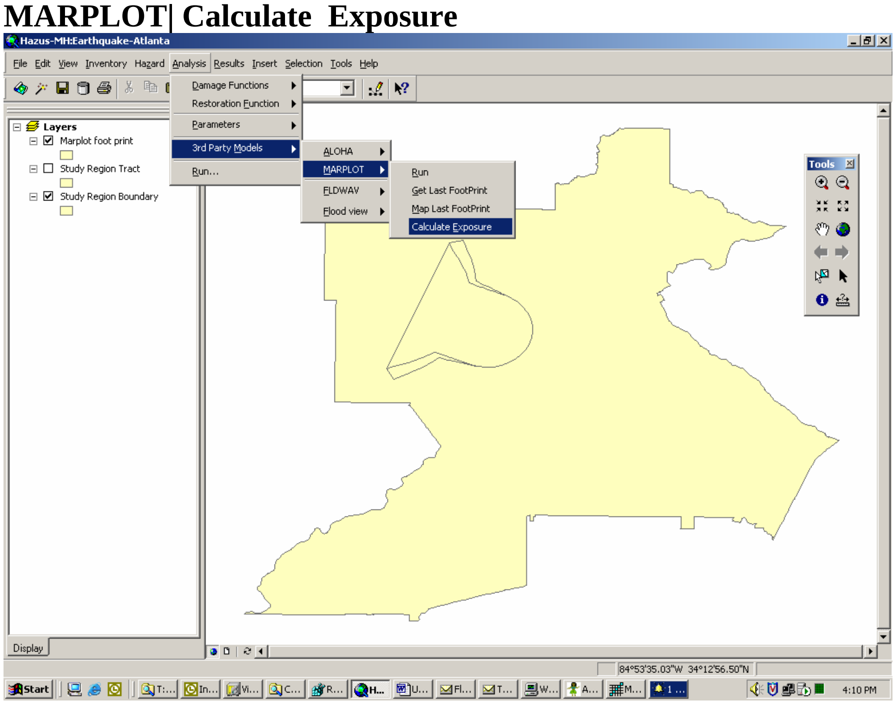


Figure L.13

13. ***HAZUS-MH*** will calculate the exposure for ALOHA/MARPLOT and prompt with completion message

Figure L.14

14. To view results select **Results |3rd party Models**

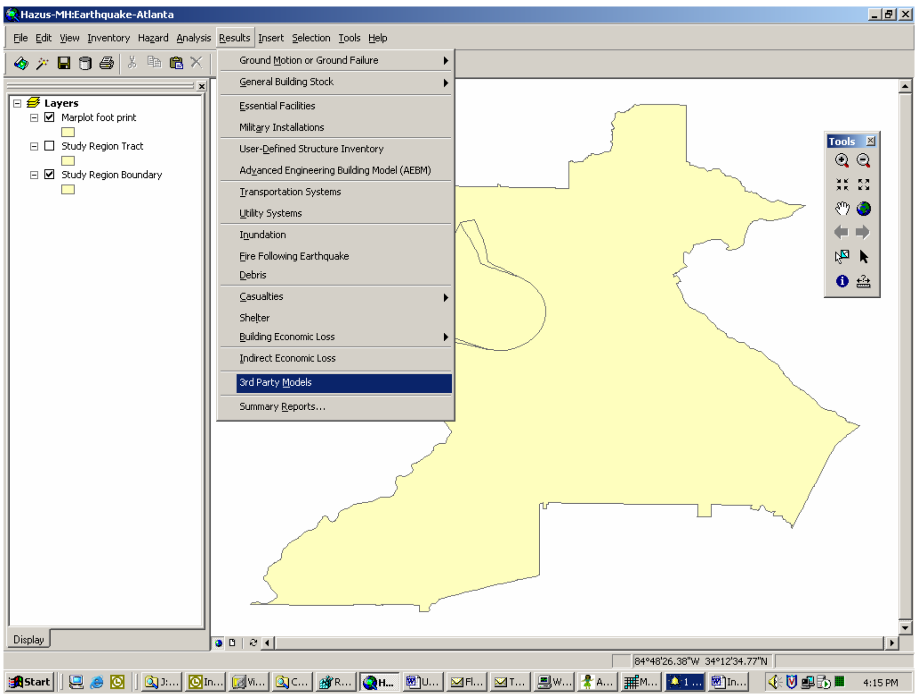
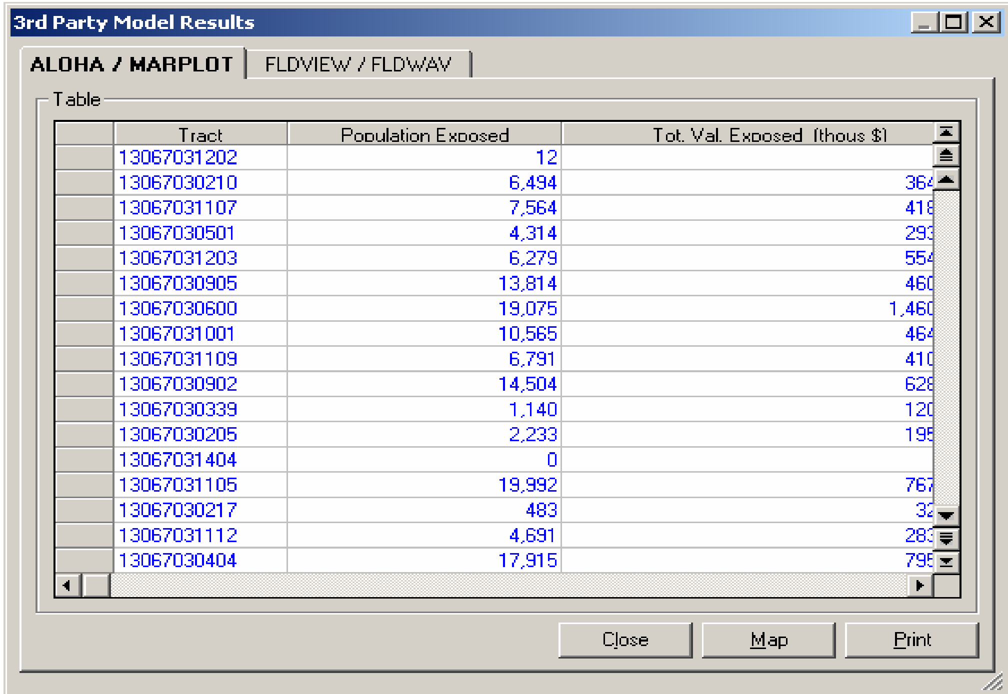


Figure L.15

15. ***HAZUS-MH*** will show the Result's browser for ALOHA/MARPLOT exposure



Tract	Population Exposed	Tot. Val. Exposed (thous $)
13067031202	12	
13067030210	6,494	364
13067031107	7,564	418
13067030501	4,314	293
13067031203	6,279	554
13067030905	13,814	460
13067030600	19,075	1,460
13067031001	10,565	464
13067031109	6,791	410
13067030902	14,504	628
13067030339	1,140	120
13067030205	2,233	195
13067031404	0	
13067031105	19,992	767
13067030217	483	32
13067031112	4,691	283
13067030404	17,915	795

Figure L.16

16. To view summary report **Results | Summary Reports**

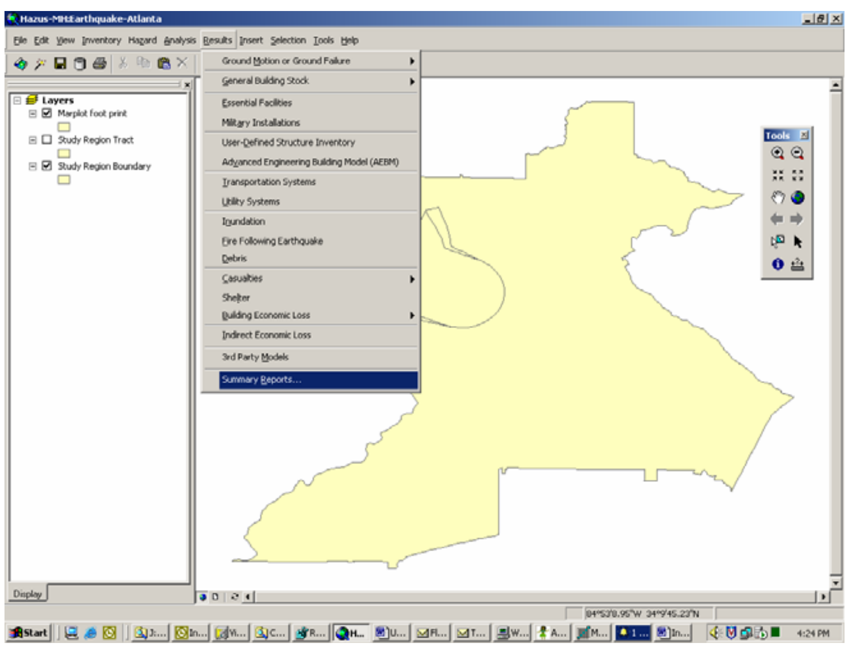


Figure L.17

17. Then go to 3rd Party Tab and Select ALOHA / Marplot Report and click view.

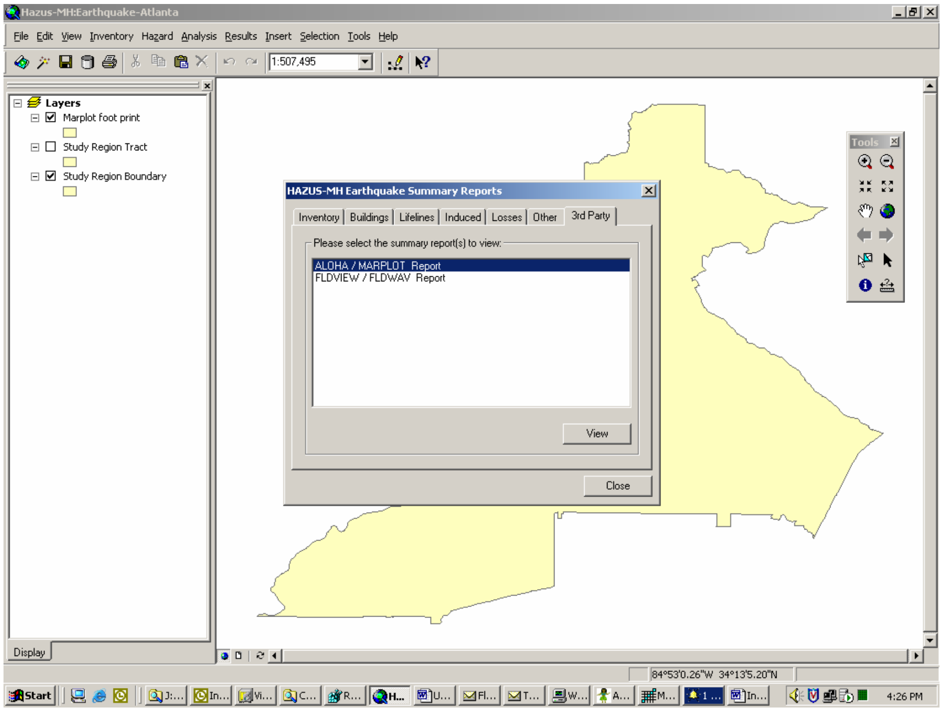


Figure L.18

18. ***HAZUS-MH*** will launch summary report for ALOHA/Marplot

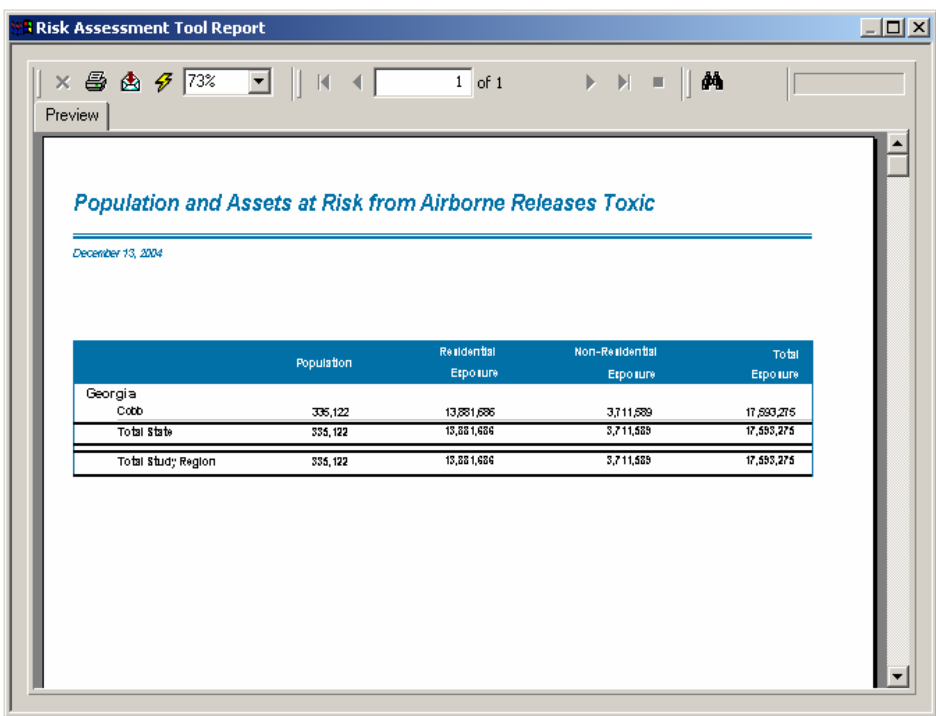


Figure L.19

Appendix M: FLDWAV / FLOODVIEW Integration with HAZUS-MH

M.1 Introduction

M.1.1 Purpose

The goal of the document is to show how FLDWAV/FLOODVIEW can be run from within HAZUS-MH and the results could be overlaid onto HAZUS-MH inventory and results.

M.1.2 Scope

This document describes how FLDWAV/FLOODVIEW could be launched from HAZUS-MH and the results from FLDWAV/FLOODVIEW could be brought into HAZUS-MH for overlay analysis. This document doesn't explain how to run FLDWAV/FLOODVIEW.

M.2 Prerequisites

HAZUS-MH doesn't install FLDWAV/FLOODVIEW as part of its installation. Before FLDWAV/FLOODVIEW could be used from HAZUS-MH, the user needs to install FLDWAV and FLOODVIEW. Once FLDWAV and FLOODVIEW are installed HAZUS-MH automatically detects the application and launches it.

M.3 Running FLDWAV and FLOODVIEW from within HAZUS-MH

1. Install ***FLDWAV*** on the computer.

2. The *DATAFILE* contains switch to let ***FLDWAV*** know how to access input/output files. FLDWAV will prompt the user for file names (DEFAULT value = 0). The user can change this value as per the instructions provided in the ***FLDWAV*** manual.

3. Prepare the ***FLDWAV*** dataset as shown in Figure M1.

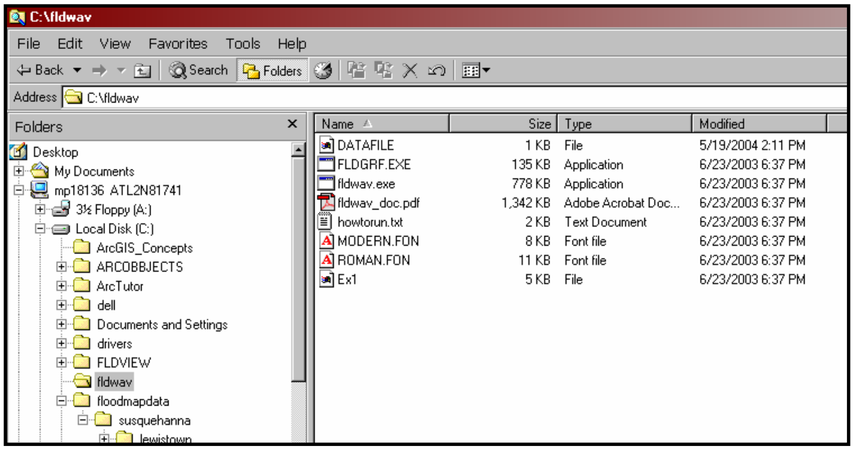


Figure M.1

4. Install ***FLDVIEW*** on the computer.
5. **For Windows 2000**

   i. Right click "***My Computer***" and select "***Properties***".

   ii. Select the "***Advanced***" tab and click "***Environment Variables***" as shown in Figure M2.

   iii. Click "New" located under the window that's titled "User variables for..."

   iv. In the "Variable Name" field type "***FLDVIEW_DIR***"

   v. In the "Variable Value" field type <full path name> as shown in Figure M3.

   NOTE - <full path name> points to the folder in which the project (.apr) is located not the actual project.

   vi. 6) Select "Ok" to close the dialog. Then "Ok" again, twice, to exit out of "My Computer"

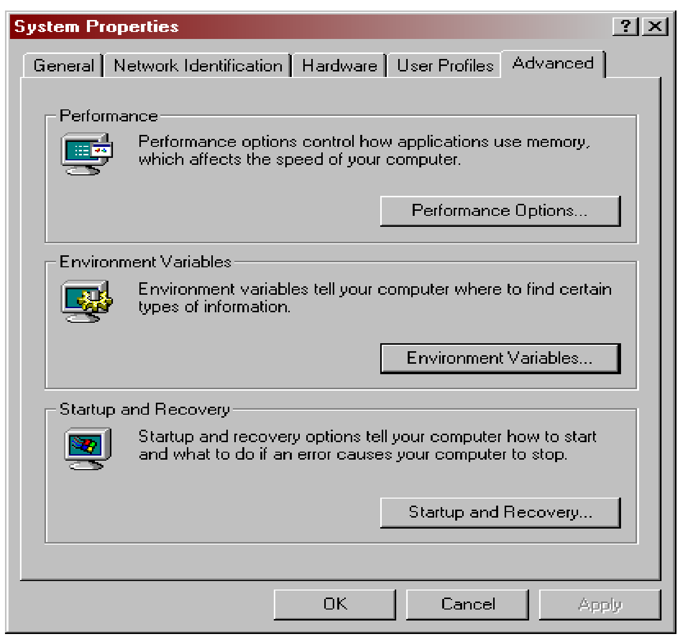


Figure M.2

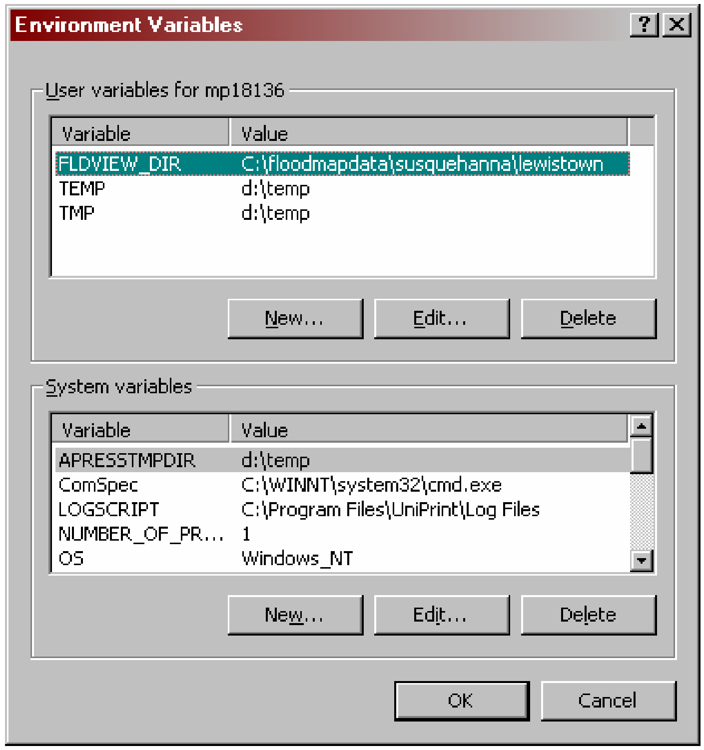


Figure M.3

6. Start ***HAZUS-MH***, aggregate the appropriate region as per the requirement at county, block or at tract level.

7. Open the region, from the menu; select the **Analysis |3rd party Models| FLDWAV| Run.**

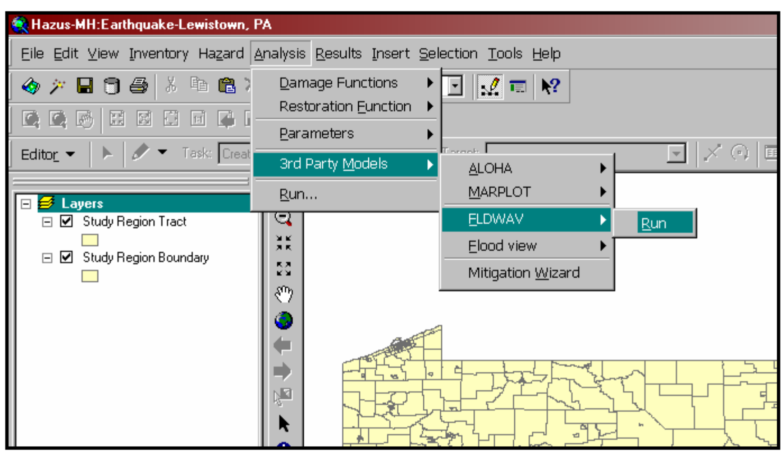


Figure M.4

8. ***HAZUS-MH*** will check whether the ***FLDWAV*** program is installed. Click yes as shown in Figure M5 and the program will look for the ***FLDWAV*** folder location and pops up a ***DOS prompt*** menu, as shown in Figure M.6, where the user can enter the input and output data file names.

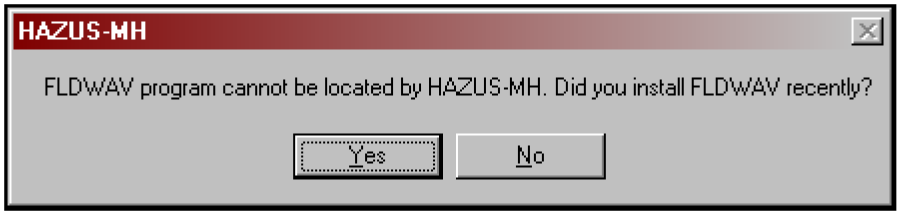


Figure M.5

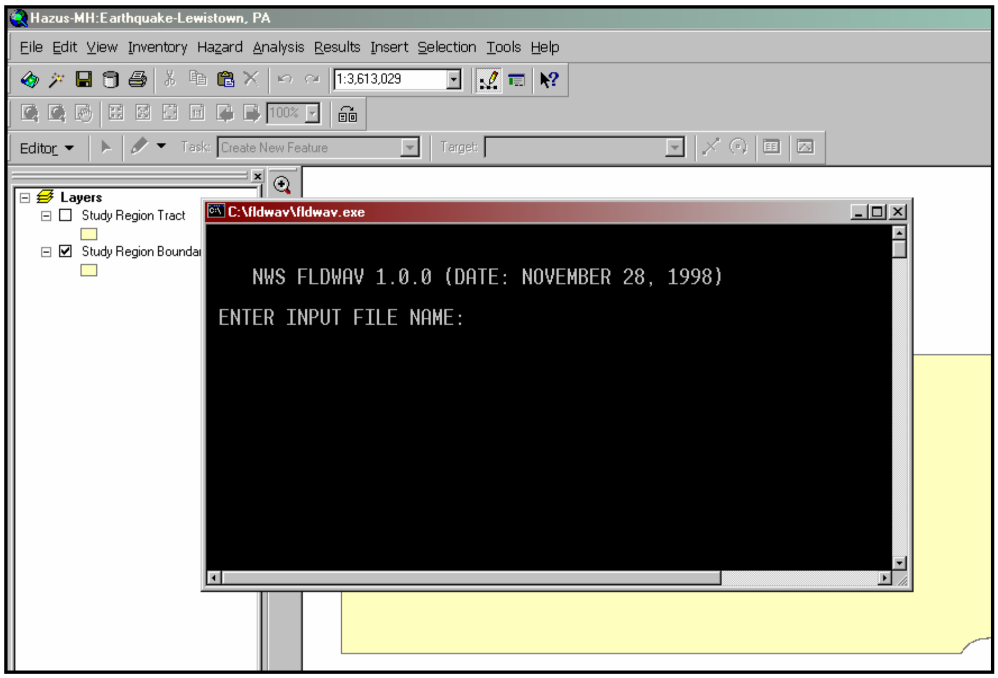


Figure M.6

9. After providing the input/output data file names, press ***Enter*** on the keyboard. The output is placed in the ***FLDWAV*** folder location (Figure M7.).

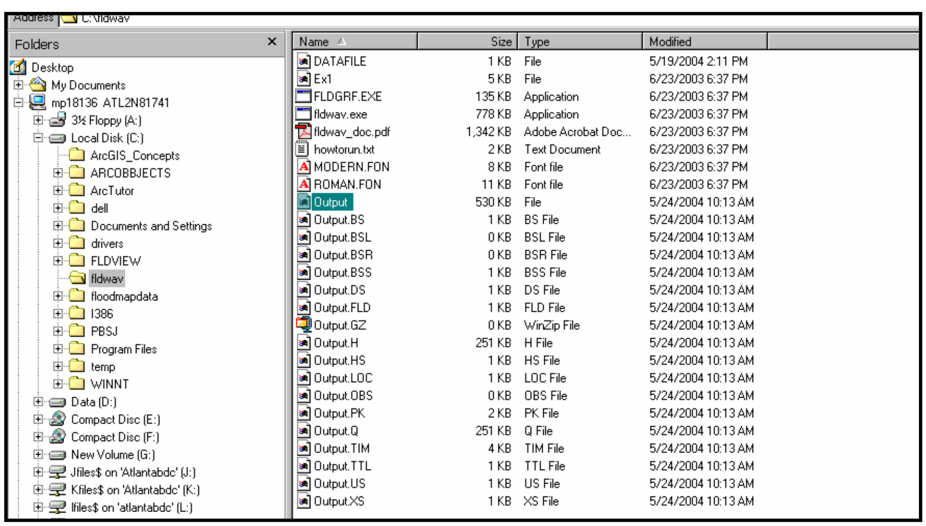


Figure M.7

10. Once ***FLDWAV*** output has been generated**,** select **Analysis**| 3**rd party Models**| **Flood View**| **Run** from HAZUS-MH (Figure M8)**.**

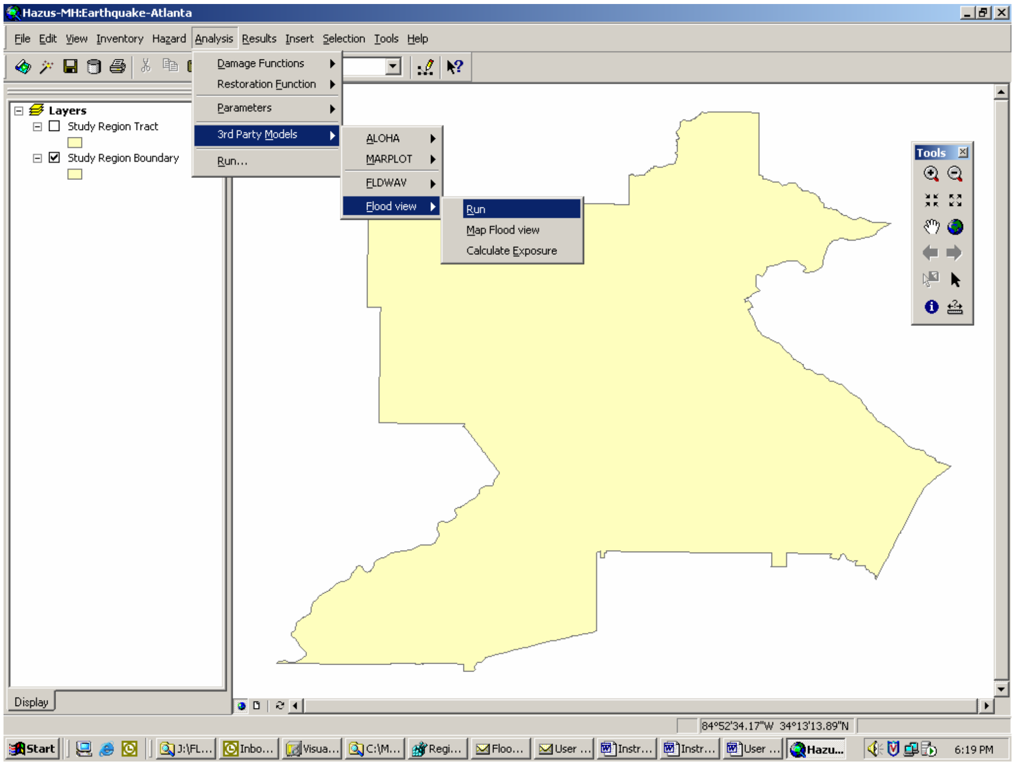


Figure M.8

11. After providing the input/output data file names, press ***Enter*** on the keyboard. The output is placed in the ***FLDWAV*** folder location
12. ***HAZUS-MH*** will check whether the ***FLDVIEW*** program is installed. Click yes, the program will look for the ***FLDVIEW*** folder location and looks for the project file to launch ***ARCVIEW***. Browse to the location of project file and click open.

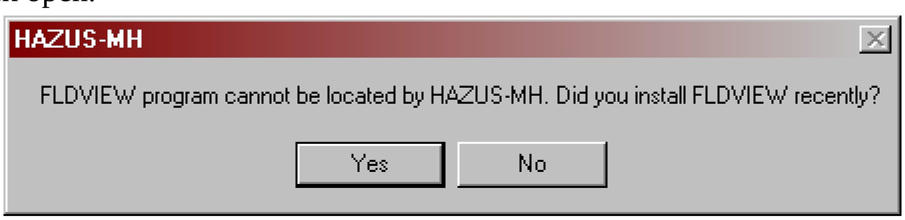


Figure M.9

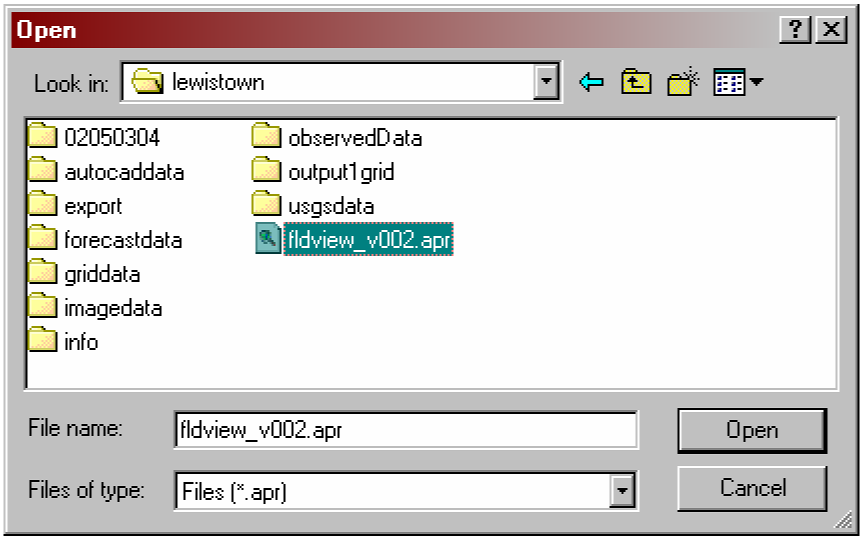


Figure M.10

13. Complete the analysis in ***FLDVIEW***. From the menu select the **Analysis| 3rd party Models| FLDVIEW| Map Flood View**. The flood map generated in the ARCVIEW is added to the Table of contents in ***HAZUS-MH***.

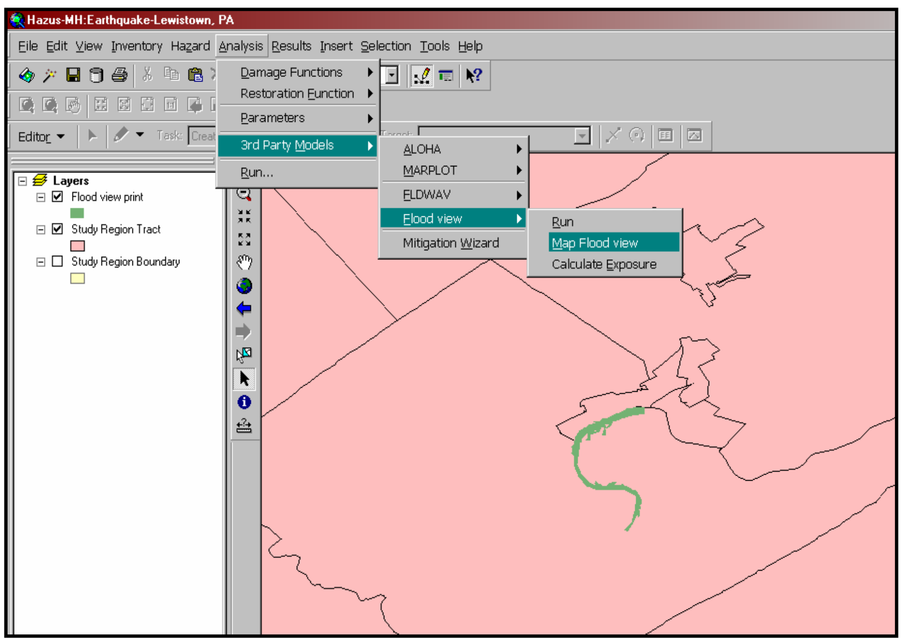


Figure M.11

14. To calculate the exposure, from the menu select **Analysis| 3rd party Models| FLDVIEW| Calculate exposure**. To view the results, from the menu select Results| 3rd party Models, which gives the exposure in thousands of dollars for the each region (county or block or tract) analyzed.

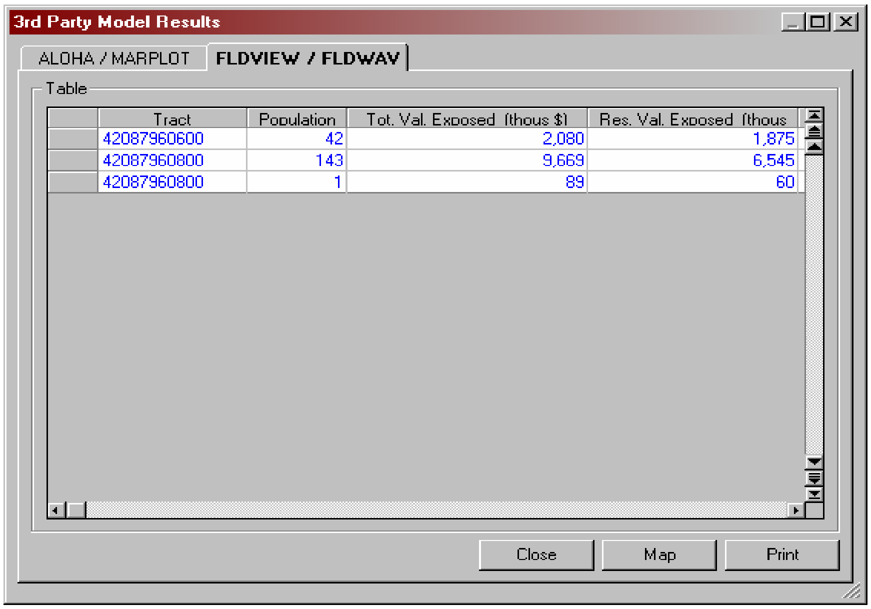


Figure M.12

Appendix N: Running HAZUS-MH with SQL Server 2005

N.1 Introduction

HAZUS-MH MR3 uses SLQ Server 2005 Express edition as the database engine. The express edition is a free and lightweight version of SQL Server 2005, and therefore has several limitations including a 4-GB database-size limit.

The purpose of this document is to show how HAZUS-MH MR3 can be configured to run with a full version of SQL Server 2005 and also how to configure HAZUS-MH back to run with the SQL Server Express-based default installation.

There are three *full* editions of SQL Server 2005 that lift the 4-GB database limit: Enterprise, Standard, and Workgroup. A special Developer edition is also available (refer to Microsoft's web site for the differences between the different editions).

HAZUS-MH has been tested to run with the ***Express Edition and SQL Server 2005 Developer Edition*** only. HAZUS-MH has not been explicitly tested to run with the other editions of SQL Server 2005 (Enterprise, Workgroup, and Standard).

HAZUS-MH neither does it install nor does it include any of the full versions of SQL Server 2005. Before HAZUS-MH can be configured to run with any of the full editions of SQL Server, the user needs to purchase and install SQL Server 2005 separately.

N.2 Purpose

This document describes all the steps that the user needs to perform to configure HAZUS-MH to run with SQL Server 2005. This document doesn't explain how to install and run HAZUS-MH. For that, refer to the Chapter 2 of the User's Manual.

N.3 Steps to Configure HAZUS-MH to Run with SQL-Server 2005

1. Install HAZUS-MH then launch it at least one time and close it.

2. Open the windows registry. To do this, click the "Start" button and select "Run" to open the Run window. Type "regedit" in the Run window edit box (**Error! Reference source not found.**) and click the "OK" button to open the Registry Editor.

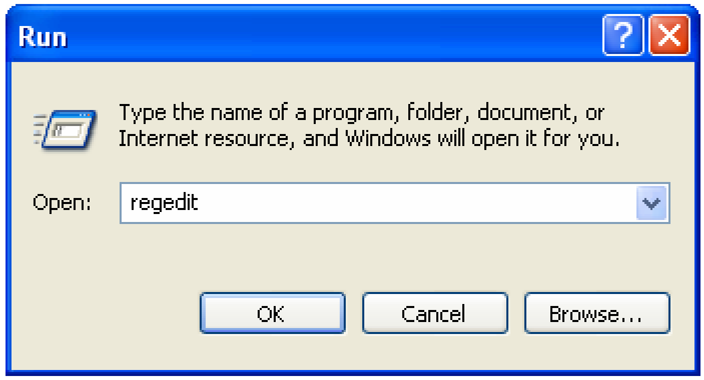


Figure N-1

3. Navigate through the folders listed in the Registry Editor to the location: [HKEY_LOCAL_MACHINE\SOFTWARE\FEMA\HAZUS-MH\General] in Registry Editor Window (**Error! Reference source not found.**).

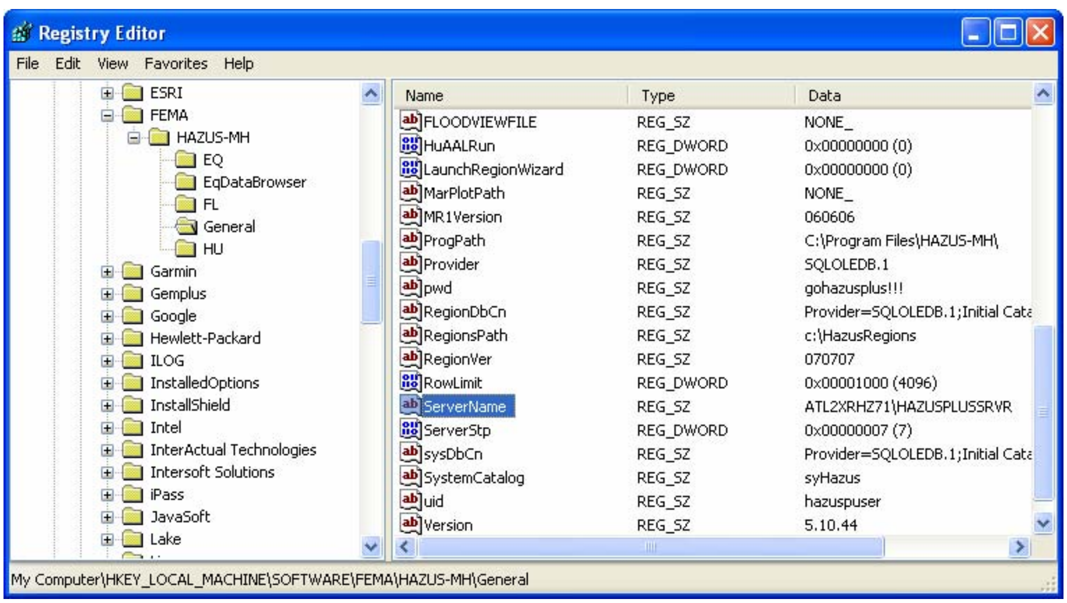


Figure N-2

4. Double click on "ServerName" (shown highlighted above in **Error! Reference source not found.**) and enter the name of the new SQL Server 2005 instance. The name is in the format <computername>/<instancename>. For example, if the machine name is ATLHW32P91 and the instance name is SQL2005[1], then the registry enter should show ATLHW32P91 \SQL2005. Open the SQL Server Management Studio from Start|Programs|Microsoft SQL Server 2005|SQL Server Management Studio on windows menu.

---

[1] The instance name is specified during the SQL Server 2005 installation.

5. Under SQL Server double click Security folder and select Logins and right click the mouse. From the Popup menu select New Login as shown in **Error! Reference source not found.**.

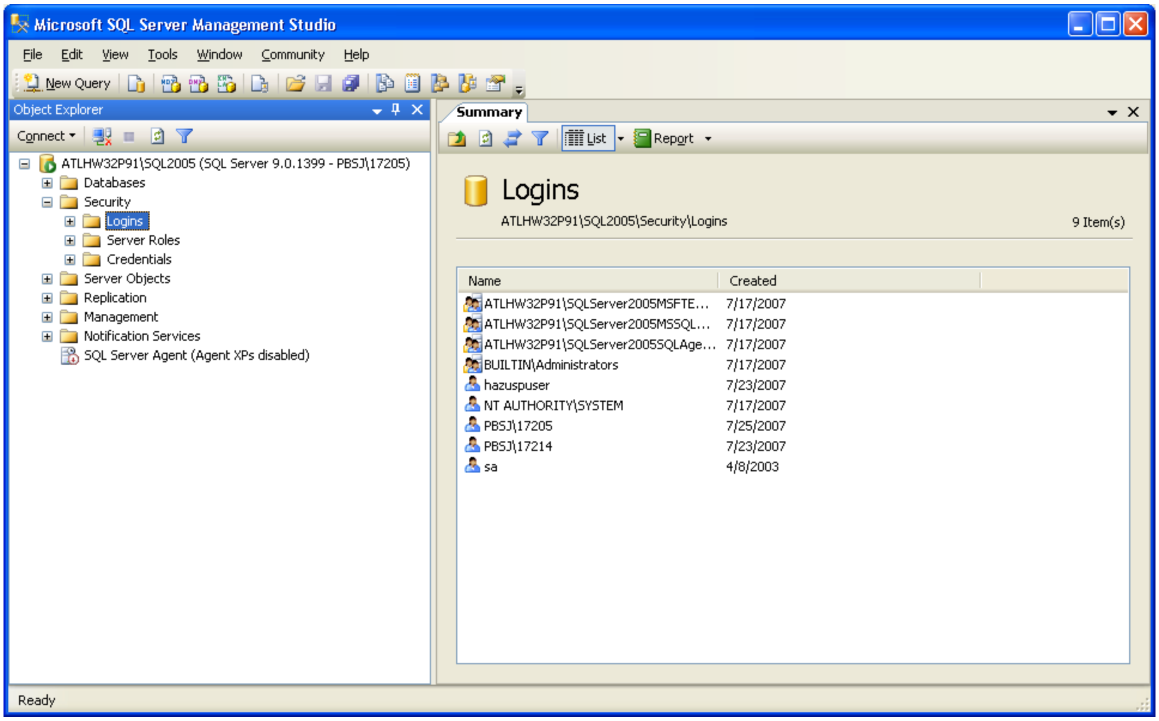


Figure N-3

6. In "SQL Server Properties -New Login" dialog enter “hazuspuser” in the name field without parentheses as shown in Figure N-4.

7. Click SQL Server Authentication option. Enter the password "gohazusplus!!!" without parentheses.

8. Uncheck the “User must change password at next login” option if it is checked.

9. Click OK.

You can get the names in 7 and 8 above by copying them from registry [HKEY_LOCAL_MACHINE\SOFTWARE\FEMA\HAZUS-MH\General] (see Figure N-2)

a. For Name field copy it from **uid** in the registry and past it in the appropriate field.

b. For Password copy it from **pwd** in the registry and past it in the appropriate field.

c. It's better to copy these values from registry to avoid typos.

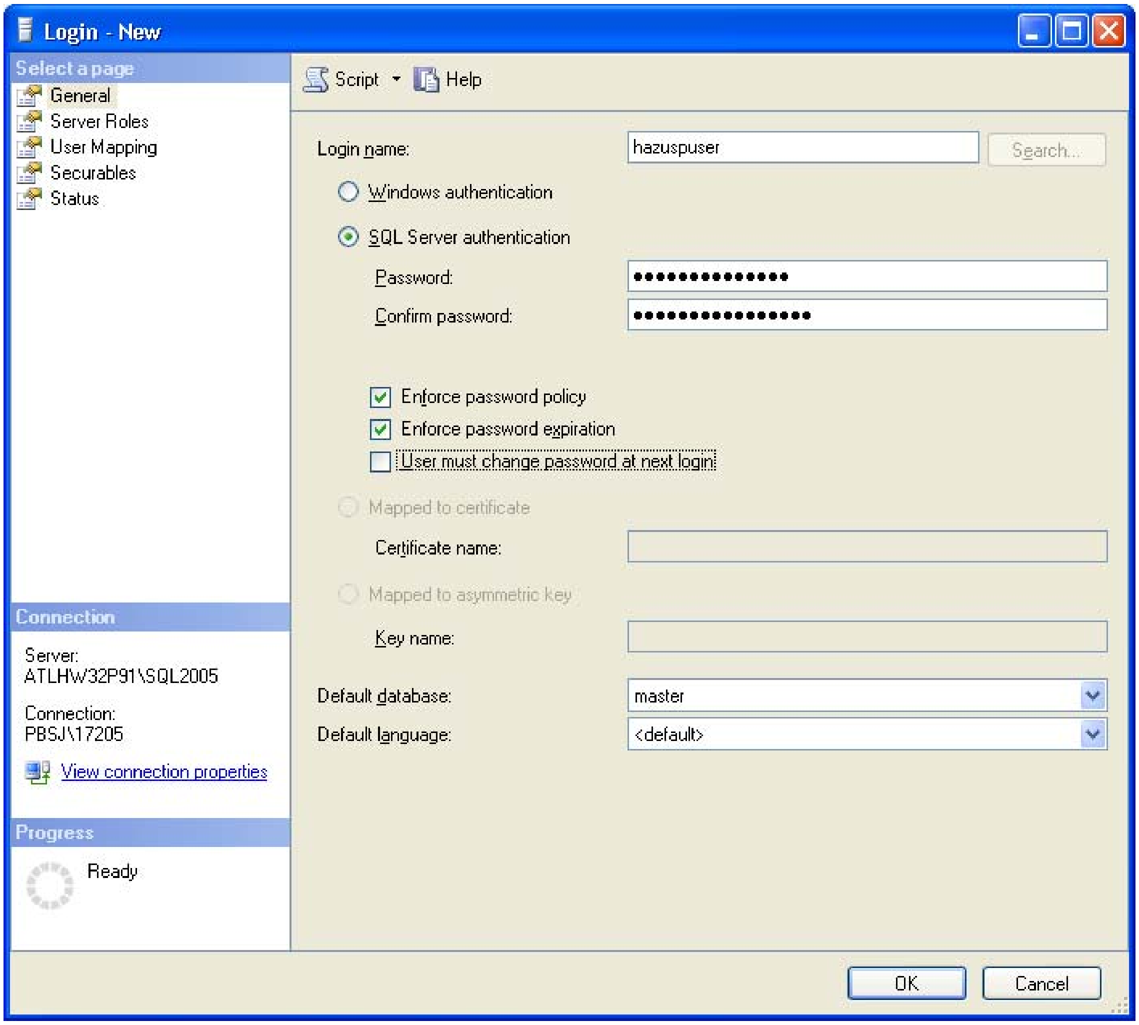


Figure N-4

10. After that Click Server Roles Tab and check sysadmin. Click OK (Figure N-5).

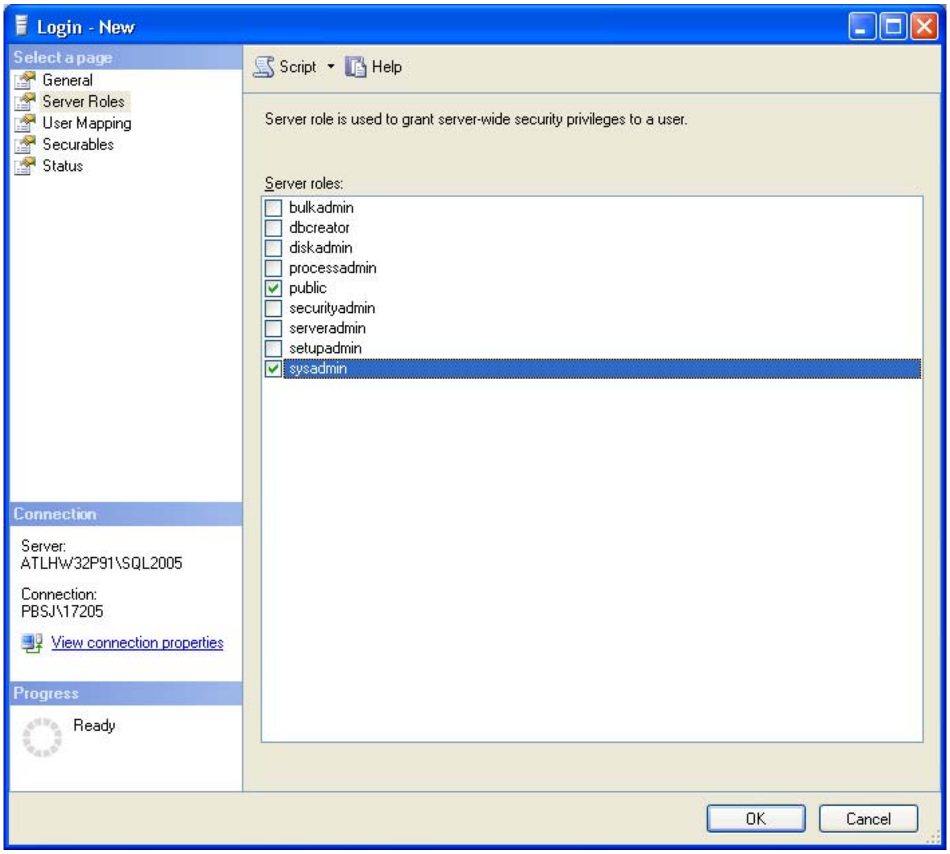


Figure N-5

11. Confirm password “gohazusplus!!!” and Click OK.

12. Now connect to the HAZUSPLUSSRVR installed by HAZUS-MH via the Management studio. To do that Click the “Connect” button at the top left corner of the SQL Server Management Studio and select Database Engine… option (Figure N-6)

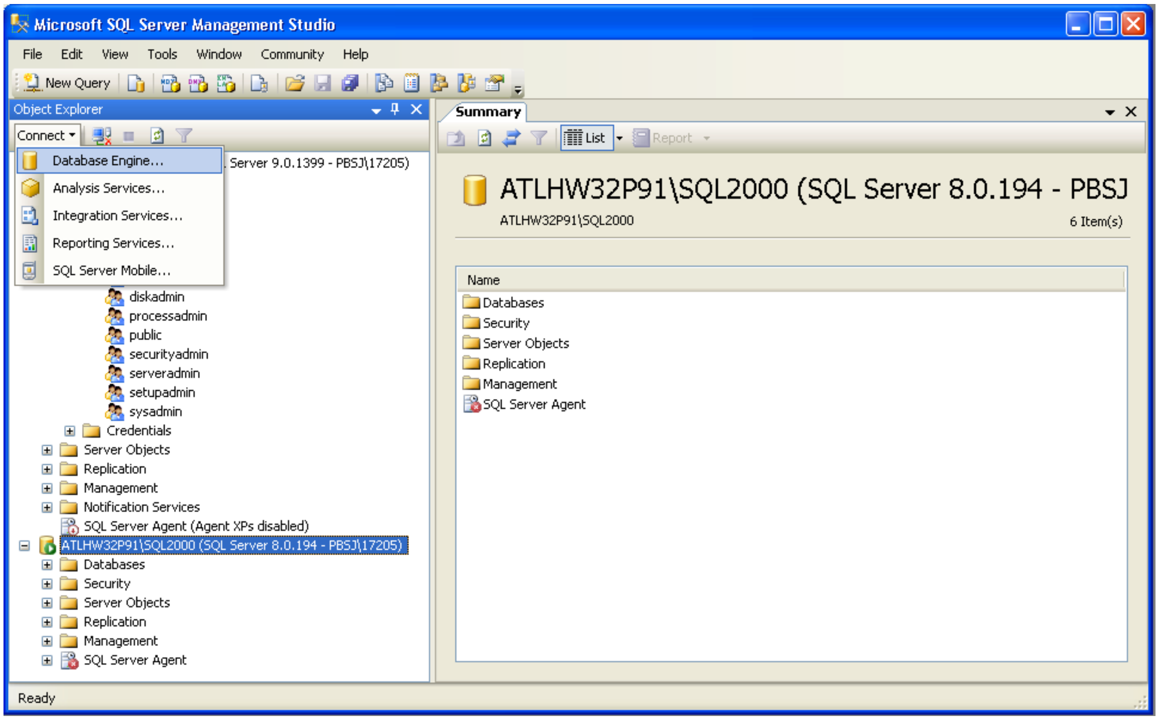


Figure N-6

13. For **Server name** select or type in YourComputerName\HAZUSPLUSSRVR.

14. Select Windows Authentication for the **Authentication**

15. Click on the **Connect** button..

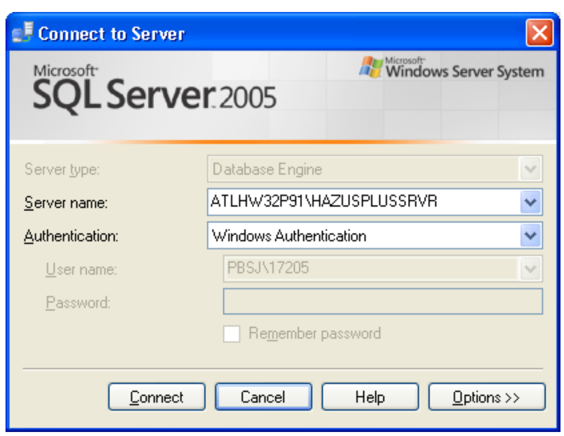


Figure N-7

16. Now, the new database server will be visible on the Management Studio as shown in Figure N-8.Figure N-7

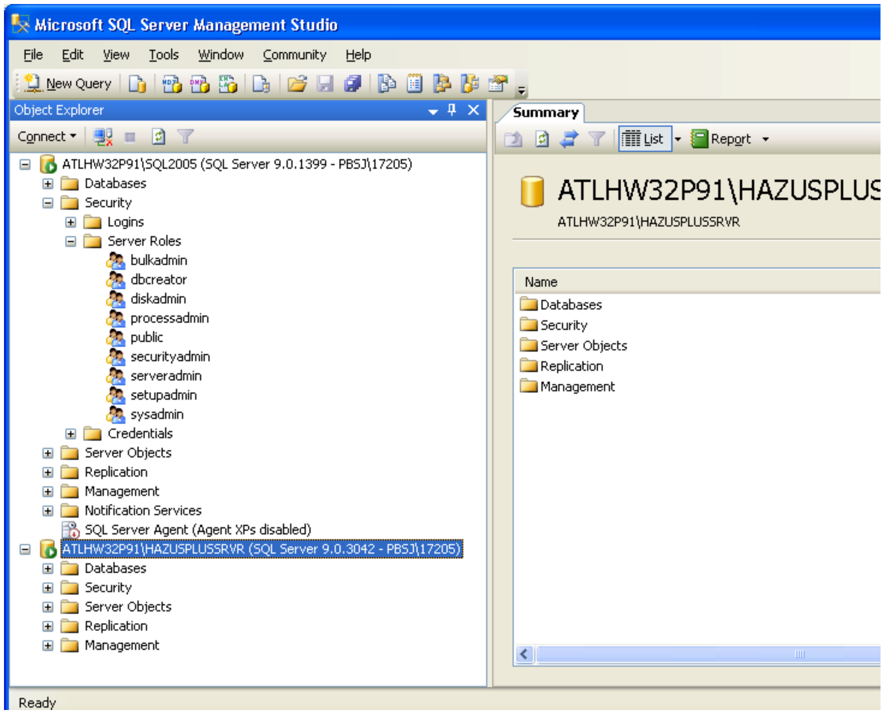


Figure N-8

17. Next navigate to Databases folder under HAZUSPLUSSRVR Server and expand it. Select syHazus database, Right click on it and Task | Detach and click OK (Figure N-9).

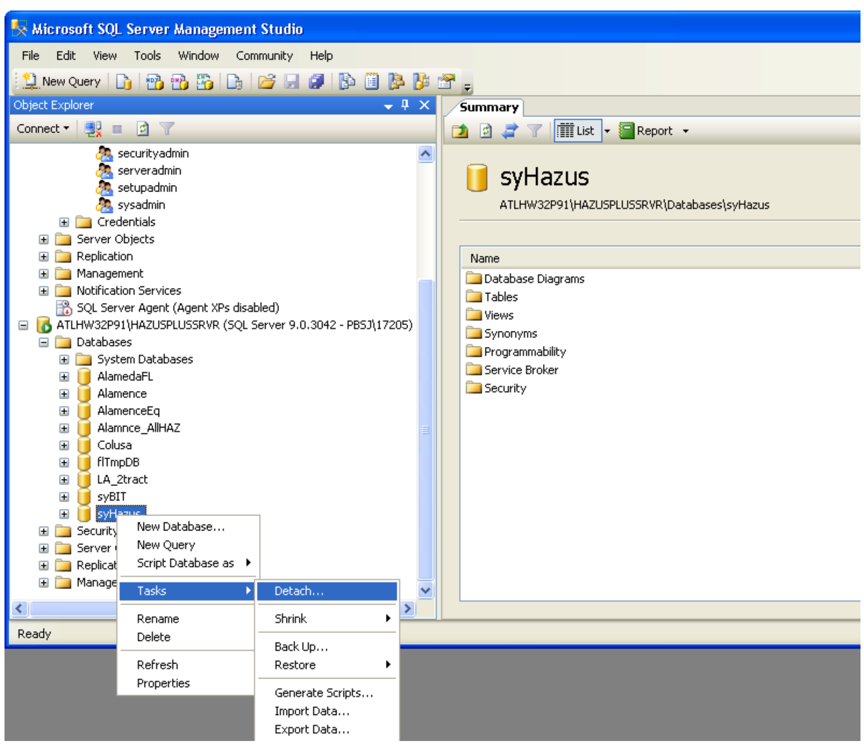


Figure N-9

18. Navigate to the folder that represents the new server (ATLHW32P91 in Figure N-10). Select Database folder and Right click the mouse, Select Attach… database... option as shown in Figure N-10.

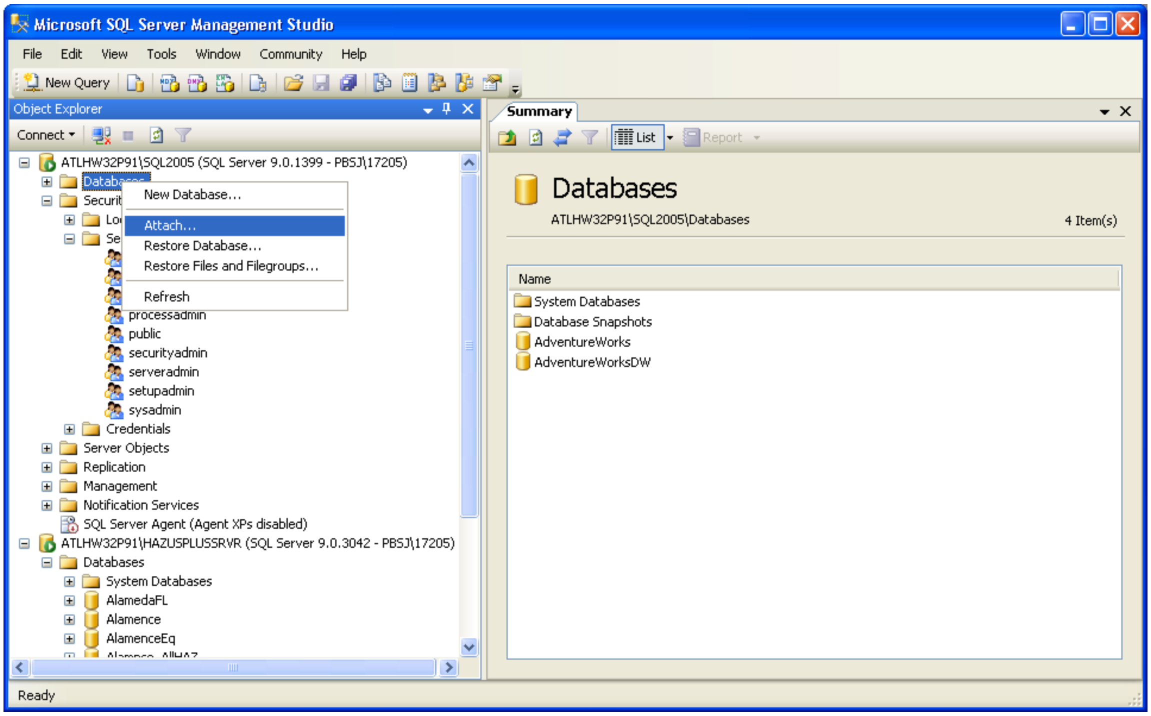


Figure N-10

19. This will launch the **Attach Database** dialog as shown in Figure N-11.

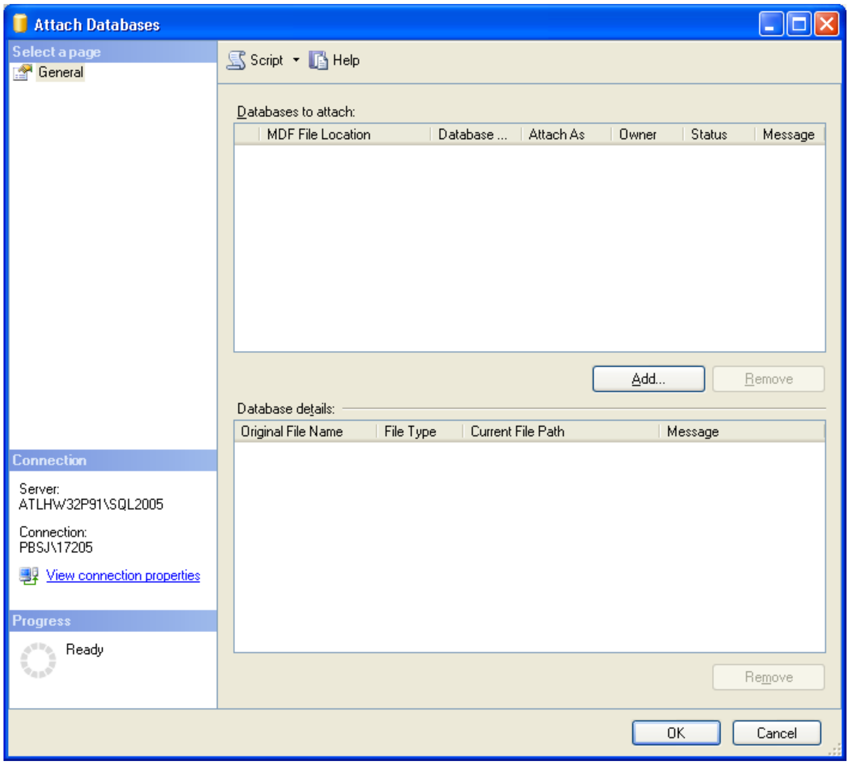


Figure N-11

20. Click Add button and browse to the folder where HAZUS-MH is installed. Within HAZUS-MH folder open Data folder (Figure N-12).

21. Select SyHazus_Data.MDF and click OK twice

22. You should get a message that the syHazus is attached successfully.

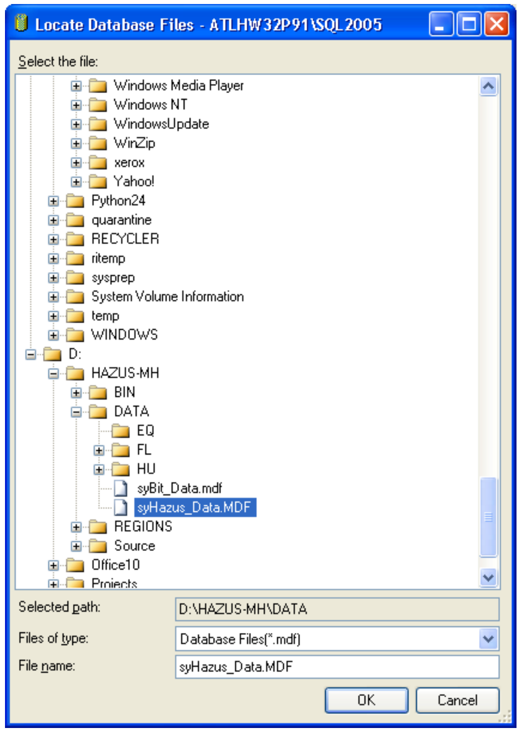

Locate Database Files - ATLHW32P91\SQL2005
Select the file:
Windows Media Player
Windows NT
WindowsUpdate
WinZip
xerox
Yahoo!
Python24
quarantine
RECYCLER
ritemp
sysprep
System Volume Information
temp
WINDOWS
D:
HAZUS-MH
BIN
DATA
EQ
FL
HU
syBit_Data.mdf
syHazus_Data.MDF
REGIONS
Source
Office10
Projects
Selected path:
D:\HAZUS-MH\DATA
Files of type:
Database Files(*.mdf)
File name:
syHazus_Data.MDF
OK
Cancel

Figure N-12

23. Right click the mouse on New Server (**ATLHW32P91** in Figure N-13) in the Managemetn Studio. Select **Properties** from the short cut menu. This will launch the **Server Properties** dialog. Click on **Security** option, and make sure that the Server Authentication is set ti **SQL Server and Windows Authentication Mode** as shown in Figure N-13.

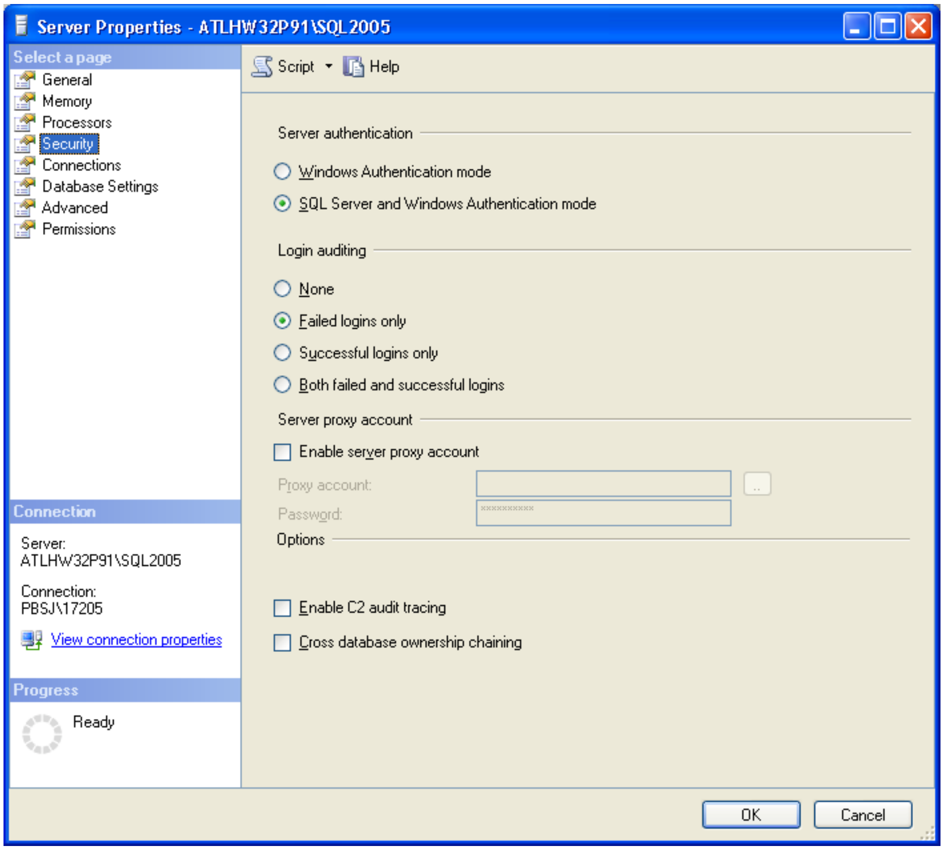


Figure N-13

HAZUS-MH MR3 is ready to be run from the New SQL Server. Proceed with creating the desired new study regions.

IMPORTANT NOTE:

Steps above are valid if the re-connection from the SQL Server Express edition to the full version of SQL Server is done right after the HAZUS-MH setup. If any number of study regions has been created already, then ALL those study regions must be also moved to the full SQL Server 2005 (follow same process above as for syHAZUS database).

N.4 Steps to Re-configure HAZUS-MH to Use Original SQL Server Express

Once HAZUS-MH has been configured to run with SQL Server 2005 it cannot be uninstalled. Before uninstalling HAZUS-MH it’s necessary to reconfigure HAZUS-MH to run with HAZUSPLUSSRVR, the way it was configured by the installation. Follow the steps outlined below to achieve this (basically, reversing the syHazus database move).

1. Launch SQL Sever Management Studio Manager.

2. Detach syHazus database from SQL Server

3. Attach syHazus to the HAZUSPLUSSRVR.

4. Launch the SQL Server Configuration Manager from **Start|Programs|Microsoft SQL Server 2005|Configuration Tools|SQL Server Configuration Manager.** Select “SQL Server 2005 Services” from the list.on the left, then select the HAZUSPLUSSRVR instance, right-click, and select Restart.

5. Restart also the full SQL server instance by following the same steps